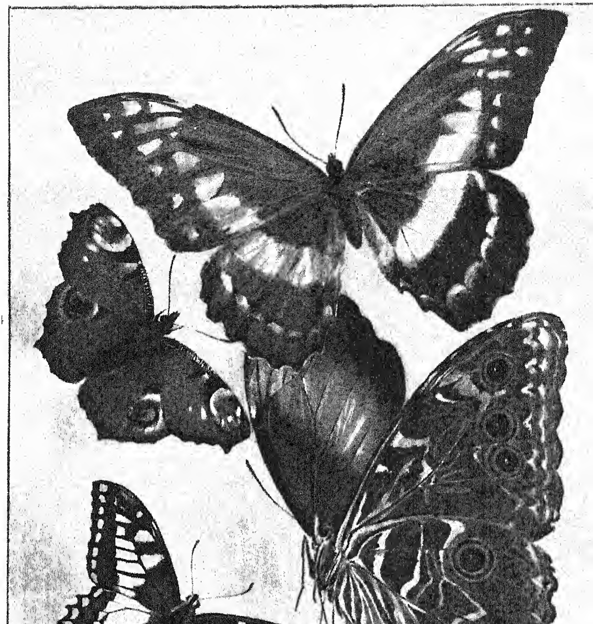

BUTTERFLIES (RHOPALOCERA)

The Natural History of Animals

The Animal Life of the World in its various Aspects and Relations

BY

J. R. AINSWORTH DAVIS, M.A.

TRINITY COLLEGE, CAMBRIDGE
PROFESSOR IN THE UNIVERSITY OF WALES, AND PROFESSOR OF ZOOLOGY AND GEOLOGY IN UNIVERSITY COLLEGE, ABERYSTWYTH

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CHAPTER VI

STRUCTURE AND CLASSIFICATION OF FISHES AND PRIMITIVE VERTEBRATES

The 7300 odd species of existing fishes known to science are divided into the following five sub-classes:—

I. Lung-Fishes (Dipnoi).
II. Bony Fishes (Teleostomi).
III. Sharks and Rays (Elasmobranchii).
IV. Chimæras (Holocephali).
V. Round-Mouths (Cyclostomata).

Probably the best idea of the general structure of the group will be obtained by briefly describing such a common example of the Shark kind (Elasmobranchs) as the Spotted Dog-Fish (*Scyllium canicula*), abundant on our shores, especially during the herring season. It may to all intents and purposes be regarded as a small shark.

External Characters (fig. 166).—The spindle-shaped body is well suited for progression through the water, and its outline is continuous, there being no sharp boundary between head and trunk, or trunk and tail. We have seen that in tadpoles and some adult Amphibia (see p. 246) there is a membranous fringe bordering the tail above and below and running forwards on the upper side of the trunk. Such a longitudinal fringe running in the middle line is known as an *unpaired fin*, and is especially characteristic of Fishes, where, however, it is not a mere soft membrane as in Amphibia, but is supported by firm rod-like structures, the *fin-rays*. We find that in the Dog-Fish, as in most fishes, this membrane is not continuous, but is represented by a number of separate pieces, each of which is named with reference to its position. Here, for example, there is a *caudal fin* bordering the tail, two *dorsal fins* in front of this above, and an *anal* or *ventral fin* in front of it on the under side. Special attention may be called

to the tail-fin, which is unsymmetrical, consisting of a large upper lobe into which the slender end of the body is continued, and a smaller lower lobe. Such unequal or *heterocercal* (Gk. *heteros*, diverse; *kerkos*, tail) tails are shown by reference to fossil forms to be of very ancient type. There is good reason to believe that remote fish-ancestors had a continuous unpaired fin, of which the existing ones are fragments which have been retained and enlarged to suit special purposes. The Dog-Fish, however, also possesses *paired fins*, consisting of two large *pectorals* in front and two smaller *pelvics* placed close together farther back. These are the equivalents of the fore- and hind-limbs of the terrestrial vertebrates so far described, but differ in important respects in accordance with differences in use. The limbs of a Salamander, for instance, have to support the weight of the body and are the means of progression. The presence of digits is of obvious advantage as regards the former, while locomotion would be difficult and awkward were the limbs not transversely divided into regions capable of being moved upon one another. But the limbs of an ordinary fish do not support the body, and their chief use seems to be that of steadying it in the water and directing its movements. For these purposes the undivided paddle-like shape which we associate with the paired fins of a fish appears best adapted.

The large curved *mouth* is situated on the under side of the head, and not far in front of it are the rounded *nostrils*, each of which is connected by a groove with the corresponding corner of the mouth. Far back on the under surface of the body, and marking the junction of trunk and tail, is a rounded *cloacal aperture* situated between the pelvic fins. On each side of this opening is a small aperture known as an *abdominal pore*, of unknown use, but commonly found in more than one group of fishes. The oblique cat-like *eyes* are provided with imperfectly movable upper and lower eyelids. A tadpole, it will be remembered, has four gill-slits on each side of the throat, the cavity of which is thus placed in communication with the exterior. Here there are five *gill-slits*, and also a superseded gill-slit known as the *spiracular cleft* and opening behind the eye by a small round hole, the *spiracle*.

The *skin* is of a brownish hue, much darker above than below, and marked with good-sized roundish spots. Projecting

from the surface are the sharp points of innumerable small hard structures, closely resembling teeth in structure and usually known as *placoid scales.* The presence of these causes a peculiar roughness suggestive of sand-paper. Numerous sense organs are present in the skin, some of which will be alluded to farther on.

The first point of general interest to note with regard to the *internal skeleton* (fig. 159) is that it is entirely made up of

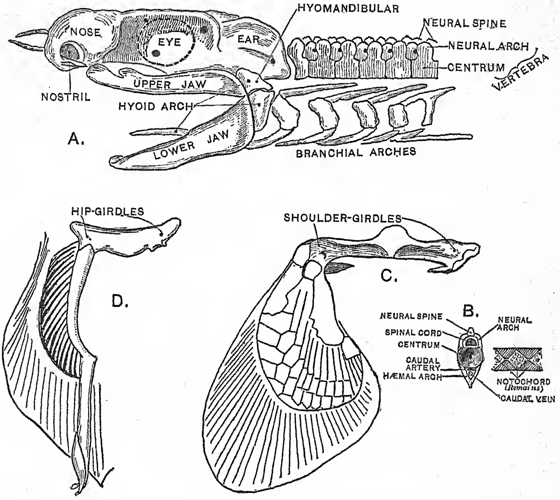


Fig. 159.—Skeleton of Dog-Fish (*Scyllium canicula*)

A, Skull and part of vertebral column. B, End view of a caudal vertebra, and longitudinal section through centra of two vertebræ. C, Pectoral fin (from below). D, Pelvic fin (from below).

cartilage and fibrous tissue, as generally in what are called "cartilaginous fishes", while in ordinary "bony fishes", including all the common edible forms, a great deal of bone is present as well as more or less cartilage.

The *skull* is extremely simple compared with that of the higher animals so far considered, and consists of a brain-case to which are attached protective capsules for nose and internal ear, the framework of the jaws, and what is known as the

"visceral skeleton". Regarding the last two a little more may be said, as they have much to do with the visceral arches and clefts which are so characteristic of Vertebrates, and have been so often alluded to in the foregoing pages (see pp. 62 and 242).

Examination of a young embryo of the Dog-Fish will show that on each side of the head there are seven oblique bar-like thickenings and six slits occupying the interspaces between them. These are respectively termed *visceral arches* and *clefts*, the hindermost five having the special name of gill arches and clefts because the gills are developed in connection with them. The first arch is the *mandibular arch* and the second the *hyoid arch*, while the slit between them is naturally called the *hyo-mandibular cleft* and is no other than the spiracular cleft of the adult. These various arches are traversed and supported by firm jointed rods forming part of the internal skeleton. The mandibular arch is so called because it becomes the mandible or lower jaw, while the upper jaw is a forward outgrowth from it. The skeleton of the rest of the arches constitutes the *visceral skeleton*, which stiffens the gill region and prevents the gill-slits from becoming closed, giving also firm points of attachment to many muscles. A special function is performed by the upper joint of the skeleton of the second or hyoid arch, this being a stout piece of cartilage (hyomandibular cartilage) which slings the jaws to the main skull. In Vertebrates higher than Fishes this cartilage loses its original function, for the jaws are directly attached to the skull, and most probably some or all of the little ear-bones, which help to conduct sound-waves across the drum of the ear in such higher Vertebrates, correspond to this cartilage. This is one of the best examples known of a change of function. The rest of the visceral skeleton, here so important in connection with the gill-clefts, dwindles in air-breathing Vertebrates to the "hyoid apparatus", which has been so often mentioned (see pp. 29, 193, and 239) as supporting the base of the tongue in these forms, and to the cartilages which support the voice-box or larynx. In the life-history of the frog the passage from a well-developed visceral skeleton in the gill-bearing tadpole to such remnants in the adult lung-possessing animal can be traced step by step.

In the *vertebral column* it is only possible to distinguish between trunk-vertebræ and tail-vertebræ, and all these possess biconcave centra, which may be regarded as the most primitive

kind. Short *ribs* can be distinguished in the trunk, but there is no trace of any sternum.

The skeleton of the *paired fins* exhibits many differences from the supporting parts of the limbs of terrestrial Vertebrates, and comparison between the two is extremely difficult. In the pectoral fin there is a very simple *shoulder-girdle*, consisting of a curved piece of cartilage running transversely and fusing with its fellow in the middle line below. At the base of the free part of the fin are three cartilages, followed by a number of others, and these again by jointed *fin-rays*. In the pelvic fins the two *hip-girdles* are represented by a simple transverse bar, while the free fin is supported by a stout rod bearing a large number of fin rays.

Digestive Organs (fig. 160).—The jaws are bordered by numerous rows of small pointed *teeth*, all much alike, and replaced by fresh ones during life as often as necessitated by wear and tear. These teeth are not suited for chewing, but for seizing such prey as small fish, crustaceans, &c., and afterwards preventing their escape. Around the margins of the mouth we find all gradations between ordinary placoid scales and teeth, which is intelligible when we recollect that the cavity of the mouth is developed as a pit on the surface of the body. The lining of such a pit, or inpushing of the general surface, so to speak, is evidently equivalent to skin, and teeth here and elsewhere are simply more or less modified scales, developed within the margins of the mouth. The *tongue* is merely an immobile fold on the floor of the mouth. The nasal organs do not possess internal nostrils as in the lunged vertebrates. The cavity of the mouth passes behind into a wide *pharynx*, out of which the spiracular cleft and gill-clefts open; and then follow gullet, U-shaped stomach, and intestine opening into a cloaca. There is no clear distinction, as in forms so far considered, between small and large intestine. Within this intestinal part of the gut is a so-called *spiral valve*, which is simply a projecting shelf winding round and round and presenting a large surface for the absorption of digested food. A large *liver* pours bile into the beginning of the intestine, and there is also a *pancreas* opening not far from it.

Circulatory Organs (fig. 160).—Here we have the same conditions as in the Tadpole before the lungs begin to be of

use, and the conditions are consequently comparatively simple, the problem of separating two kinds of blood not having yet arisen. The *heart* consists of a thin-walled venous sinus, which receives the impure blood of the body and passes it on to a single auricle, by which it is squeezed into a thick-walled ventricle, continued again into a muscular tube, the arterial cone. Valves to prevent the blood from running back the wrong way are placed at the points of junction between sinus,

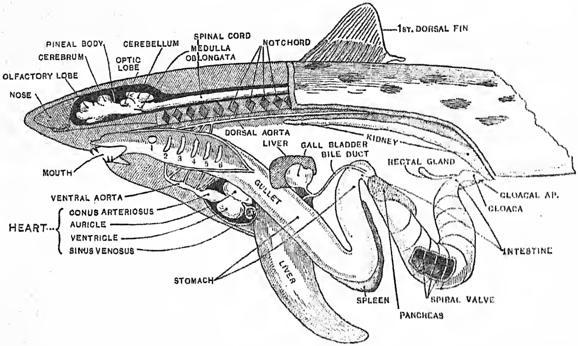


Fig. 160.—Side-dissection of Dog-Fish (*Scyllium canicula*). Left half of liver has been removed
1, Internal opening of spiracular cleft. 2, 3, 4, 5, 6, Internal openings of gill-clefts.

auricle, and ventricle, and several transverse rows of valves are present in the arterial cone. From the *ventral aorta*, which runs forward from the cone, five pairs of *afferent* gill-arteries run out and carry impure blood to the gills, from which five pairs of *efferent* gill-arteries conduct the purified blood, uniting above to form the *dorsal aorta* that runs back to the end of the tail, giving off numerous vessels by which the various organs and regions receive their pure blood-supply. Each afferent artery, with its corresponding efferent one, may be looked upon as constituting an *aortic arch* (see p. 242).

Breathing-organs (fig. 160).—Upon the walls of the five pairs of gill-slits, or pouches, to speak more correctly, numerous closely-set gill-folds are placed, and in these folds there are very numerous capillary blood-vessels, with which the gill-arteries are in communication. Water is constantly taken in

at the mouth, and, passing back, streams outwards through the gill-pouches—thus passing over these folds, which collectively present a large surface over which the oxygen dissolved in the water can diffuse into the blood, while the waste carbon dioxide of the blood can diffuse outward into the water and be carried away to the exterior.

In this connection great interest attaches to the spiracular cleft, which looks very much like a narrow gill-pouch, and on close examination is seen to have a number of small folds on its front wall. These are so gill-like that they have been collectively called a *false gill* (pseudobranch), and when it is added that some few fishes possess a properly-developed set of gill-folds in this place, it will be clearly seen that the spiracular cleft is really a gill-cleft which is losing its function. There is every reason to believe that the cavity of the middle ear in higher Vertebrates, together with the Eustachian tube, is equivalent to the spiracular cleft. Here, then, is a structure which once had to do with breathing and is now concerned with sound-conduction—another excellent example of change of function.

Nervous System and Sense Organs (fig. 160).—The *brain* is pretty well developed, a peculiar feature being that the two cerebral hemispheres are represented by an unpaired swelling, while the olfactory lobes are placed on stalks. The cerebellum is much larger than in Amphibia.

The *eyeball* is flattened on the outside and its crystalline lens is approximately spherical, as in aquatic animals generally. Probably everyone has noticed, some time or other, the lens in the eye of a cooked bony fish, such as salmon or herring, looking, as it does, like a sugar-coated pill. Needless to say, the opacity is the result of cooking. Here, too, the lens is spheroidal. The *organs of hearing* consist simply of the internal ear or membranous labyrinth, contained in a gristly capsule on either side of the back end of the brain-case. In shape the labyrinth is somewhat simpler than in the Amphibia. The *skin* contains a large number of sense-organs, some of which are sunk in a tube which runs along each side of the body and opens to the exterior at intervals. An external streak, the *lateral line*, marks the position of either tube, but this is much better seen in a bony fish than in the Dog-Fish. There are also peculiar *jelly-tubes* which open by regularly arranged pores

on the under side of the head, and undoubtedly have to do with sensation. Little is known of the use of these organs, but they no doubt respond to certain vibrations in the surrounding water. It is important to avoid the common error, made when dealing with the sense-organs and sensations of lower animals, of trying to explain them by reference to ourselves.

Development.—The Dog-Fish is developed from an egg, which looks almost like the "yolk" of a fair-sized bird's egg were it not for its greenish tint. This egg is enclosed in a horny "purse", the corners of which are drawn out into tendril-like threads which curl round sea-weeds and other firm objects.

We may now proceed to the consideration of the chief groups of Fishes.

SUB-CLASS I.—LUNG-FISHES (DIPNOI)

Of all known fishes these come nearest to the Amphibia, and some zoologists place them in a class of their own, distinct from that containing more ordinary fishes. They are a very ancient group, now represented by only three genera, all of which are found in fresh water. They are the Barramunda or Burnett Salmon (*Ceratodus*) from the Burnett and Mary rivers in Queensland; the African Lung-Fish (*Protopterus*), native to some of the rivers of tropical Africa; and the South American Lung-Fish (*Lepidosiren*), found in the Amazon and upper part of the Paraguay rivers and their tributaries (fig. 161).

There are certain characters common to all three forms. Taking first the *external characters*, the head is somewhat amphibian-like, and has been compared to that of a salamander, while the tail tapers considerably and is symmetrically margined by a fin which is not expanded into lobes (protocercal or diphycercal caudal fin). There is no spiracle, but gill-clefts are present, protected by a flap or *gill-cover*. The paired fins are much elongated, and the body is covered by thin overlapping scales.

The most characteristic feature of the internal organs is the presence of one or two bag-like *lungs* opening on the under side of the pharynx, so that these animals possess, like some adult Amphibia, both gills and lungs at the same time, and it is from this circumstance that they derive the name of Dipnoi (Gk. *dis*, twice; *pnoe*, breath).

Since the heart receives pure blood from the lung or lungs, as well as impure blood from the general body, the problem of separating the two kinds demands solution; but this is only effected in an imperfect manner, for there is not even, as in Amphibia (see p. 240), a complete separation of the two auricles which are here present.

These are the only fishes in which there are *internal nostrils* as well as external ones. They open just within the margin of

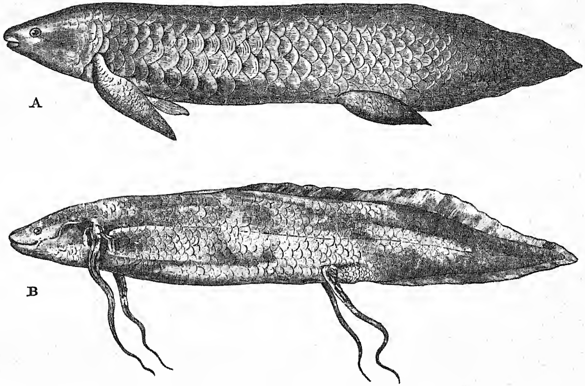


Fig. 161.—Dipnoi
A, Australian Lung-Fish (*Ceratodus*), $\times \frac{1}{7}$. B, African Lung-Fish (*Protopterus*), $\times \frac{1}{4}$.

the upper lip. The mouth is provided with large dental plates of peculiar form.

Ceratodus is a large broad fish, attaining the length of 4 or 5 feet, and with its body covered by very large scales. The paired fins are broad and paddle-shaped, and each of them is supported by a central axis made up of numerous joints, and of a series of fin-rays attached to the axis in front and behind in a feather-like way. *Protopterus* is much more slender in form and its paired fins are extremely narrow, the fin-rays on the central axis being largely suppressed. Some specimens are said to reach a length of 6 feet. There are small external gills as well as the gill-folds on the walls of the gill-clefts. *Lepidosiren* is an eel-like form which may be as much as 6 feet long. Its

paired fins are even narrower than those of Protopterus, and supported only by a central jointed axis.

SUB-CLASS II.—BONY FISHES (TELEOSTOMI)

This large group of fishes includes a vast number of recent and fossil forms which present such varying characters that it is difficult to give a satisfactory definition. There is, however, a good deal of bone in the skeleton, and the jaws, instead of being mere bars of gristle, as in a Dog-Fish, are ensheathed by tooth-bearing bones in the same way as in higher forms. The gill-clefts are very near together, and the gill-arches between them are comparatively narrow, so that the gill-folds as seen in a Dog-Fish are not supported along the whole of their length, but project more or less to the exterior as free *gill filaments*. The gill-clefts are covered over and protected by a flap, the gill-cover or *operculum*, which is supported by bones. Two orders may be distinguished:—1. Ganoids, and 2. Bony Fishes proper or Teleosts.

Order 1.—GANOIDS (Ganoidei)

Under this name are included a number of recent genera, widely scattered over the globe, and for the most part limited to fresh water (fig. 162). They are the last surviving remnants of groups which were once of great importance, but which have been unable to compete with more highly-organized fishes, and have greatly declined in consequence. Of recent forms the two most primitive are the Bichir (*Polypterus*) of the Nile and some other African rivers, and the Reed-Fish (*Calamoichthys*) from the rivers of Old Calabar. The former is a remarkable-looking creature of respectable size, being as much as 4 feet long. Running along the back are a considerable number of little dorsal fins, each with a strong spine in front, while the last of them abuts against the rounded protocercal fin of the tail, close to which, on the under side, is an anal fin. The paired fins consist of a thickened basal part, supported by cartilages something like those described for Dog-Fish (see p. 261), and fringed by a thinner region supported by radiating fin-rays. The body is covered by thick lozenge-shaped bony plates (ganoid

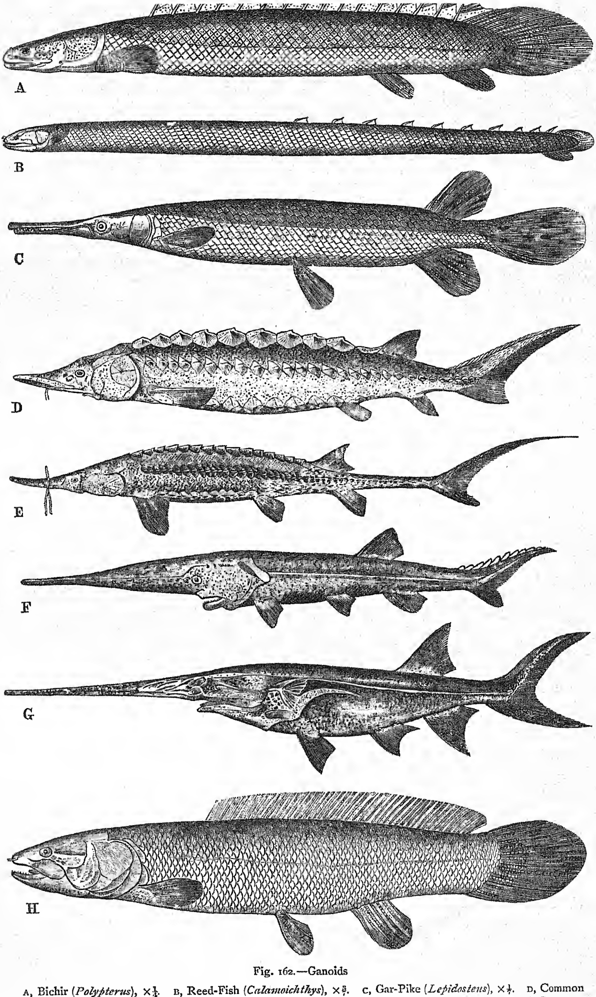


Fig. 162.—Ganoids

A, Bichir (*Polypterus*), $\times \frac{1}{4}$. B, Reed-Fish (*Calamoichthys*), $\times \frac{3}{7}$. C, Gar-Pike (*Lepidosteus*), $\times \frac{1}{7}$. D, Common Sturgeon (*Acipenser*), $\times \frac{1}{24}$. E, Shovel-nose Sturgeon (*Scaphirhynchus*), $\times \frac{1}{7}$. F, Slender-beaked Sturgeon (*Psephurus*), $\times \frac{1}{8}$. G, Spoonbill Sturgeon (*Spatularia* or *Polyodon*), $\times \frac{3}{8}$. H, Bow-Fin (*Amia*), $\times \frac{3}{10}$.

scales), united firmly by their edges and having a very regular arrangement in oblique rows, while the head is covered by paired bony plates.

The Reed-Fish is what a small Bichir might be imagined to become if it were pulled out into an eel-like form and lost its pelvic fins.

Both these forms are distinguished as "Fringe-finned" Ganoids on account of the structure of the paired fins; while the remaining recent Ganoids are "Ray-finned", *i.e.* the paired fins have lost the thickened basal portion and consist of a fan-like expansion strengthened by the numerous diverging fin-rays, which may be compared to the sticks of the fan. These ray-finned forms include the Gar-Pikes, Sturgeons, and Bow-Fins of the present day.

The Gar-Pike (*Lepidosteus*) is common in the fresh waters of North America, and may be as much as 6 feet long. Covered with firm armour like the Bichir, it differs not only in the structure of the paired fins, but also in the presence of a single dorsal only, while the head is drawn out into long but powerful jaws.

Sturgeons are large fishes which have lost more or less of the dermal armour, have a much elongated snout, and an unsymmetrical tail like that of the Dog-Fish (see p. 258). The mouth is on the under side of the body, at the base of the snout. The Common Sturgeon (*Acipenser*) includes some twenty species, of which the largest, a Russian form, is as much as 30 feet in length. It is distinguished by its broad pointed snout, on the under side of which are four sensitive thread-like structures (barbels), and the presence of rows of broad keeled plates in the skin. Sturgeons of this kind are widely distributed through the fresh waters and along the coasts of the Northern Hemisphere. One species (*Acipenser sturio*) is British, and may occasionally be seen in fishmongers' shops.

The Shovel-nose Sturgeon (*Scaphirhynchus*), native to the Mississippi and the rivers of Central Asia, is of more elongated form than the common form, and its dermal armour is more complete, especially in the hinder part of the body.

The two remaining kinds of Sturgeon both have teeth, while the sorts so far mentioned are toothless; and they are further distinguished by enormous snouts and the complete, or almost complete, absence of armour. One, the Slender-beaked Sturgeon (*Psephurus*) of the Yang-tse-Kiang and Hoang-ho rivers has a

conical snout, and the other a broad flattened one, as is indicated by the name of Paddle-Fish or Spoon-bill Sturgeon (*Spatularia*). It is found in the Mississippi.

The last remaining recent Ganoid, the Bow-Fin (*Amia*), resembles the ordinary bony fishes in many respects, and was for long confused with them. Its body is covered by thin overlapping flexible scales. In distribution it corresponds to the Gar-Pike.

One structural feature in which all these Ganoids differ from the Dog-Fish is the possession of an elongated air-containing sac, the swim-bladder or *air-bladder*, which opens into the pharynx, usually on the upper side. In the Bichir, however, the air-bladder, like the lungs of terrestrial Vertebrates, is paired, and opens into the under side of that region. The original use of the swim-bladder is apparently that of a balancing organ, but in some Ganoids (Bichir, Gar-Pike, Bow-Fin) it assists in breathing, and in the Dipnoi has been converted into a lung. It is highly probable that the lungs of the higher Vertebrates are simply to be regarded as modified swim-bladders, and if so, an extremely interesting example of change of function is afforded.

Order 2.—Ordinary Bony Fishes (Teleostei)

Here are included the ordinary bony fishes of the present day, which include some three thousand existing species. The most important features of the group may be understood by briefly describing an average form, such as the common freshwater Perch, and noting the differences between it and the Dog-Fish (see pp. 257–264).

The Common Perch (*Perca fluviatilis*) (fig. 163) is widely distributed through the fresh waters of Europe and North Asia, and is very beautifully coloured. The upper parts are of a warm reddish-brown, passing into golden on the sides and again into white below. Several broad dark bands run across the body, tapering off on the sides. Well-grown specimens in this country attain a length of 9 or 10 inches, or even a foot, but much larger specimens have been recorded.

The body is much flattened from side to side and the outline is spindle-shaped. It has been compared to a rounded wedge, eminently adapted for rapid progression through the water by

means of the powerful lateral strokes of the large tail-fin, while the remaining fins act as balancers and steerers. The fairly large mouth, its jaws supported by bones bearing small teeth, is placed at the end of the pointed head, and above it may be seen two external nostrils, one on either side of the snout. Farther back still come the large, round, expressionless eyes,

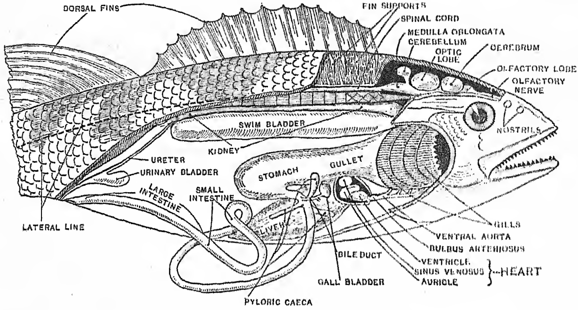


Fig. 163.—Side-dissection of Perch (*Perca fluviatilis*)

devoid of eyelids, but there are no spiracles behind them. No gill-slits are externally visible, but these may be seen by lifting up the firm gill-cover or *operculum* placed at the side of the head as in a Ganoid. Four such slits are present, instead of five as in the Dog-Fish (see p. 258), with four narrow bar-like gill-arches bearing the red, comb-like gills, the separate teeth of the combs being the gill-filaments. The gill-openings here are really slit-like, and not pouches as in Dog-Fish, and their existence is practically demonstrated by every school-boy who strings his small catches on a piece of grass, which he threads through the mouth and gill-slits under the gill-cover to the exterior. It is further of great interest to notice that on the inner side of the gill-cover, close to the first gill-slit, there is a small reddish projection. This *false gill* (pseudobranch) is the vestige of the first gill present in a Dog-Fish, and must not be confused with the false gill of that animal (see p. 263), which is on the front wall of the spiracular cleft, here entirely absent.

The *unpaired fins* consist of two large dorsals, of which the

first is supported by exceedingly sharp spines, of an externally symmetrical (homocercal) caudal fin shaped like a fan, and an anal fin, quite close to which is the external opening of the intestine, for there is here no cloaca. Fan-shaped *pectoral* and *pelvic fins* are present, of the rayed type found in living Ganoids except the Bichir and Reed-Fish, and it may be noted that the latter are placed very far forward, much more so than in many other Teleosts. The *lateral line*, marking the position of important sense-organs (see p. 263), is indicated by a dark streak running along either side of the body about the level of the eye. The body is covered by thin overlapping scales.

The *internal skeleton* is complicated by the presence of a large number of bones, and contrasts strongly with the comparatively simple cartilaginous skeleton in Dog-Fish (see p. 259). The *skull* is particularly elaborate, and it must suffice to mention once more the presence of tooth-bearing bones bordering the jaws, which are attached at the back to the main skull by a hyo-mandibular bone equivalent to the cartilage of the same name in Dog-Fish (see p. 260). And as the Dog-Fish possesses no operculum, it has nothing corresponding to the bones which support that structure here.

The skeleton by which the base of the tail is supported presents some points of great interest. It will be remembered that in the Dog-Fish the tail is unsymmetrical (heterocercal), the vertebral column bending upwards and running into its upper lobe. Here, on the contrary, the expanded tail is externally symmetrical (homocercal), and the backbone apparently stops short at its base. Examination of certain very young Teleosts, however, shows that in them the tail is unsymmetrical, the backbone bending up in the characteristic way, and close examination of the apparently symmetrical tail of the adult shows that behind the last joint of the backbone is a little bony rod which turns upwards, and marks what is really the posterior end of the body. The homocercal tail, therefore, is really a modification of the old-fashioned heterocercal one, and may be looked upon as an improved type which has arisen from it.

Digestive Organs (fig. 163).—Small pointed teeth are present on the roof of the mouth-cavity as well as on the margins of the jaws, and the usual regions of the gut are present, *i.e.* mouth-cavity itself, pharynx out of which the gill-slits open,

gullet, stomach, and intestine, the last not opening into a cloaca as in Dog-Fish, nor provided with a spiral valve (see p. 261). A large liver is present, but the pancreas appears to be represented physiologically by some blindly-ending tubes (*pyloric cæca*) which open into the beginning of the small intestine.

The *Circulatory Organs*, broadly speaking, are constructed on the same type as in Dog-Fish (see p. 261), though important differences are seen in the *heart*, which no longer possesses an arterial cone with numerous rows of valves, but presents a new structure, the arterial bulb (fig. 163), which succeeds the ventricle, and is really the swollen beginning of the ventral aorta, which, as before, runs forwards on the floor of the gill-region, and gives off the afferent branchial arteries that carry the impure blood to the gills to be purified.

The only *organs of respiration* are the gills, of which enough has been said to give an idea of their arrangement.

Nervous System and Sense Organs (fig. 163).—The *brain* presents the same regions as in a Dog-Fish (see p. 263), but is shorter and broader. The olfactory lobes are not placed on stalks, and there are two cerebral hemispheres instead of an unpaired projection, while the cerebellum is smooth and tongue-shaped.

Two obvious points as regards the *sense-organs* may be mentioned. One is that the nasal sacs have no internal openings into the mouth-cavity as in Dipnoi, but are distinguished by the possession of double external nostrils; while the other peculiarity is a negative one and consists in the absence of the numerous jelly-tubes so characteristic of the Dog-Fish (see p. 263).

A membranous *swim-bladder* (fig. 163) is present, situated above the other internal organs, close to the under surface of the backbone, but though it contains air, it has lost in the adult all connection with the gullet, and therefore cannot play even a subsidiary part in respiration.

Little more can be done here than briefly mention some of the more important or interesting types of bony fishes, but even so, it will make things clearer to indicate the chief groups. which are as follows:—

A.—Teleosts in which the swim-bladder when present has lost its connection with the gullet.

Sub-order 1.—Spine-finned Fishes (Acanthopterygii).
Sub-order 2.—Tuft-gilled Fishes (Lophobranchii).
Sub-order 3.—Firm-jawed Fishes (Plectognathi).
Sub-order 4.—Soft-finned Fishes (Anacanthini).

B.—Teleosts in which the swim-bladder retains its connection with the gullet by a pneumatic duct or tube.

Sub-order 5.—Tube-bladdered Fishes (Physostomi).

Sub-order 1.—Spine-finned Fishes (Acanthopterygii)

Here as in the Perch, which is a type of the sub-order, some or all of the fin-rays which support the dorsal, anal, and pelvic fins are sharp unjointed spines. Some 3650 different species are here included, divided into about 60 families, of which only a few can be mentioned.

1. *Perch Family* (fig. 163).—This is a group of carnivorous fishes, almost entirely confined to fresh water and distributed through the northern hemisphere.

2. *Bass Family*.—This is a large group of fishes, which are for the most part marine though some inhabit fresh water, and which have a very wide distribution. A well-known British species is the Common Bass (*Morone labrax*), which is much like the Perch, but more slender in build and not so brilliantly coloured, being bluish-grey above, gradually shading off to white on the under surface.

3. *Sword-Fish Family*. — The members of this family are large fishes, mostly found in the open sea, and deriving their name from the formidable sword-like weapon into which the upper jaw is produced. The Common Sword-Fish (*Xiphias gladius*) is sometimes taken in British seas, and occurs on both sides of the Atlantic. Other species are found in the Atlantic and Pacific. These fishes have become notorious from the fact that their swords have been found broken off in the timbers of ships, penetrating to a depth of as much as 22 inches (in a specimen exhibited in the British Museum). The force with which such blows have been given may be imagined.

4. *Dory Family*. — This includes marine fishes of extraordinary form, found in the East Atlantic, Mediterranean, and the seas of Australia and New Zealand. The John Dory (*Zeus faber*) is not uncommonly found in British seas. The body is much flattened, and with the head has a broad oval outline.

From behind each of the sharp spines of the large first dorsal fin projects a long filament. A small part of the upper side is dark-brown, which shades into golden-yellow farther down, and again into brownish white. On each side of the body there is a large round blotch, dark in colour with a lighter margin. By the ancient Romans it was regarded as sacred to Neptune.

5. *Mackerel Family.*—This is an important group of carnivorous food-fishes, abundant in the temperate and tropical seas of both hemispheres. They are remarkable for their powers of swimming. The Common Mackerel (*Scomber vernalis*) suggests the lines of a racing-boat in the beautifully graduated curves of its rather slender body, terminated behind by a well-developed caudal fin shaped like the head of a broad arrow. Rows of pointed finlets fringe the body in the spaces between the tail and the anal and second dorsal fins.

Another member of the family, sometimes taken off the south of England, and the object of an important Mediterranean fishery, is the Tunny (*Orcynus thynnus*), which may attain the length of 10 feet and a weight of more than 1000 pounds. Smaller species of the same genus are the Bonito (*Thynnus pelamys*) and Albicore (*Thynnus albicora*), which prey largely on Flying-Fishes, and, being rendered conspicuous by this habit, are often mentioned in accounts of voyages.

6. *Angler-Fish Family.*—This embraces widely-distributed fishes of extraordinary form, some of which frequent shallow water, while others drift with sea-weed in the open ocean, and still others live at great depths. A well-known British species is the Fishing-Frog (*Lophius piscatorius*), with its body dwarfed by an enormous head, the wide gaping mouth of which, armed with numerous teeth, is a regular death-trap for unwary little fishes of all sorts. The first dorsal is reduced to its long spines, the foremost of which terminates in a soft flap. The upper side is of a blackish brown and the under side white.

7. *Bull-Head Family.*—These are small ground fishes of wide distribution, and mostly found near to land, while there are also fresh-water forms. A common British species is the Bull-head or Miller's Thumb (*Cottus gobio*), common in brooks, as every school-boy knows; while just as common along our shores is the Sea-Scorpion (*Cottus scorpius*), which has much the same appearance.

8. The *Gurnards* are larger relatives of the preceding and are distinguished by their curiously-shaped bony heads, and by the fact that the first three rays of the pectoral fin have become distinct and form "fingers" used as organs of touch and in progression along the sea-bottom. They are fishes of wide distribution and often of bright coloration. The commonest British species is the Red Gurnard (*Trigla pini*), which is bright red in colour above and gleaming white below and on the sides.

9. *Goby Family.* — Gobies and their allies are small fishes common along the coasts of both tropical and temperate seas, while some are estuarine and a few inhabit fresh water. There are nearly a dozen British species, of which the largest and probably on that account best known is the Rock Goby (*Gobius niger*). In these fishes the pelvic fins are united into a funnel-shaped sucker.

10. *Blenny Family.* — The fishes of this family are mostly small and have the same wide distribution as the Gobies. The pelvic fins are very much reduced, and there is a single dorsal running along the whole length of the back, and equivalent to the two dorsals of perch fused together. A common British species is the Smooth Blenny or Shanny (*Blennius pholis*), in which the long, low dorsal fin is not broken into sections. The Wolf-Fish (*Anarrhichas lupus*), common on the north British coasts and ranging to Norway and Greenland, may be over 6 feet long, and resembles the Shanny on a large scale. The margins of its jaws and the roof of the mouth are studded with blunt teeth, adapted for breaking the coverings of molluscs and crustacea.

11. *Grey Mullet Family.* — Grey Mullets are common along the coasts of tropical and temperate regions, frequenting estuaries. The first dorsal fin is small, with only four spines, and the lateral line is absent. The best-known British species is the Common Grey Mullet (*Mugil capito*).

12. *Mackerel-Pike Family.*—Here are included Gar-Fishes and Flying-Fishes. The former are distributed throughout tropical and temperate seas, and the Common Gar-Fish (*Belone vulgaris*) is common on the British coasts. The body is much elongated and the snout is lengthened into a narrow pointed beak, well suited for seizing small fish. *Flying-Fishes* include a considerable number of species limited to the warmer parts of the ocean. The

Common Flying-Fish (*Exocœtus volitans*), found in all tropical seas, has immensely elongated pectoral fins, which constitute the so-called wings.

13. *Stickleback Family.*—The familiar little fishes constituting this family are mainly, but not entirely, inhabitants of fresh water, and are only found in the Arctic and North Temperate zones. The name is derived from the fact that the first dorsal fin is represented only by its spines, of which there are a variable number. There are three common British species, all of them nest-builders. Of these the largest is the Sea Stickleback (*Gastrosteus spinachia*), with fifteen spines. It also frequents brackish water. The other two kinds live in fresh or brackish water, the smaller being the Ten-spined Stickleback (*Gastrosteus pungitius*) or "Tinker", while the other is the Three-spined Stickleback (*Gastrosteus aculeatus*).

14. *Wrasse Family.*—Wrasses are widely-distributed shore fishes, being absent, however, from the polar regions, and are especially numerous on rocky coasts and coral reefs. Most of them are handsomely coloured, and some are pre-eminent among fishes in this respect. The bones which constitute the bases of the skeleton supporting the gill-arches (lower pharyngeal bones) are fused together into a single tooth-bearing piece. Many members of the group are distinguished by the possession of thickened lips, and all have blunt conical teeth suitable for crushing the shells of molluscs and crustacea, of which the food consists. There are a number of British species, of which one of the commonest is the Ballan Wrasse (*Labrus maculatus*), a stoutly-built fish of some 15 inches long. The colour is of a bright brown with numerous whitish spots, and touches of green on the fore-part of the head and the bases of the fins. Some individuals, however, are of a greenish colour all over. The spiny first dorsal is long and low, while the soft second dorsal is much shorter and higher.

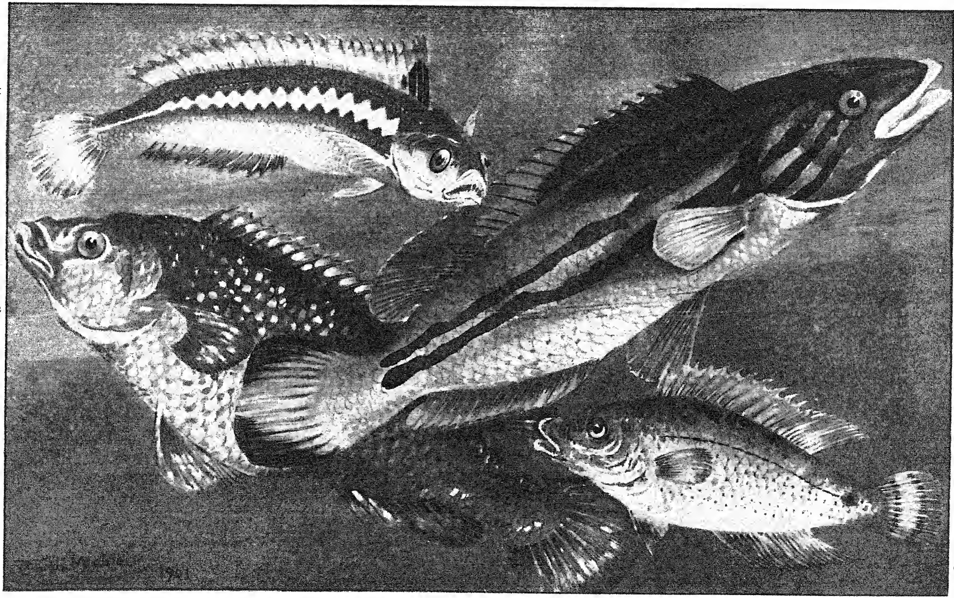
Sub-order 2.—Tuft-gilled Fishes (Lophobranchii)

This small sub-order includes about 120 species of curiously modified fishes, in which pelvic fins usually, and anal and caudal fins commonly, have disappeared. The snout is drawn out into a tube, at the end of which the small rounded toothless mouth

WRASSES (*Labridæ*)

Wrasses are tropical and temperate shore fishes, possessed of thick lips and crushing teeth well suited to the food, which consists of molluscs. Many of them are beautifully coloured. All four of the species figured are native to the seas of Britain. Their names are:—

1. Rainbow Wrasse (*Coris julis*).
2. Ballan Wrasse (*Labrus maculatus*).
3. Cuckoo Wrasse (*L. mixtus*), male.
4. Corkwing (*Crenilabrus melops*).



WRASSES (LABRIDAE)

1. Rainbow Wrasse. 2. Ballan Wrasse. 3. Cuckoo Wrasse. 4. Corkwing.

is situated. Scales are absent, but their place is taken by bony plates developed in the deeper part of the skin and arranged in regular transverse rings. The name of the group (Gk. *lophos*, a tuft; *branchia*, gills) has reference to the gill-filaments, which are arranged in tufts and not in combs as in ordinary Teleosts. The male fish usually has a pouch in the skin on the under side of the body in which the eggs are developed and the young protected.

The Great Pipe-Fish (*Syngnathus acus*) is a common British species, with much-elongated cylindrical body and a small caudal fin. A much more extraordinary looking species is the Short-snouted Sea-Horse (*Hippocampus antiquorum*) (fig. 164), which has a very wide range and is sometimes found off the British coast. The name is suggested by the shape of the head, which is sharply bent on the trunk and separated from it by a sort of neck. The animal maintains a vertical position in the water, both when swimming and also when attached to sea-weed by means of its prehensile tail, which is devoid of a caudal fin.

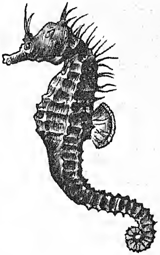


Fig. 164.—Sea-Horse (*Hippocampus*)

Sub-order 3.—Firm-jawed Fishes (Plectognathi)

This also is a small group, embodying about 180 species, most of which have a well-developed external skeleton. There is as a rule nothing to correspond to the spiny first dorsal and pelvic fins of a perch, except, perhaps, a few spines. The gill-cover is not a large free flap, but is united with the surrounding parts so as to leave only a small aperture through which the water which has passed over the gills can flow out to the exterior. The internal skeleton is deficient in bony matter, but the bones of the upper jaw are very firm and fused to the main mass of the skull, a feature which the name of the sub-order suggests (Gk. *plektos*, woven together; *gnathos*, jaw). The included species are characteristic of tropical seas, though not confined to them, and include: 1. File-Fishes; 2. Coffer-Fishes; 3. Globe-Fishes; and 4. Sun-Fishes.

1. *File-Fishes* constitute a widely distributed family, in which

the skin is rough and there is a small spiny first dorsal fin, of which the first spine is ridged like a file on its front surface. The firm jaws, provided with strong teeth, are well adapted for breaking open the shells of molluscs, or nipping off pieces of coral. The Mediterranean File-Fish (*Balistes capriscus*) has occasionally been taken in British seas.

2. *Coffer-Fishes* are curious-looking creatures in which the body is almost entirely protected by numerous six-sided plates united by their edges. The Four-horned Coffer-Fish (*Ostracion quadricornis*) has been taken off the coast of Cornwall.

3. *Globe-Fishes* mostly have their bodies covered with strong spines, and possess the power of dilating the gullet with air, when the body swells out into a globe-like form and the spines are erected, furnishing a formidable protection. In this condition they are unable to swim, but are drifted along with the under side turned upwards. In the genus *Diodon* there is a bony plate in the front of each jaw, while in the allied genus *Tetrodon* each of these plates is divided into two, giving the appearance of four large front teeth.

4. *Sun-Fishes* are remarkable for the shortness and depth of the body, the caudal fin forming a border to the hinder end, which does not taper as in an ordinary fish. Adjoining the caudal fin is a long pointed dorsal above and a similar anal below.

Sub-order 4.—Soft-finned Fishes (Anacanthini)

In these fishes the rays which support the various fins are all soft and jointed, and the pelvic fins are situated very far forwards. There are some 370 species, of which many are of great economic importance. Only two of the included families need be mentioned here, *i.e.*: 1. the Cod Family, and 2. that in which the Flat-Fishes are included.

1. *Cod Family.*—The Common Cod (*Gadus morrhua*) (fig. 1) is the most important representative of a genus distinguished by the possession of three dorsal and two anal fins, while in this and some of the other species of the genus there is a filament or barbel attached to the lower jaw. The Cod abounds on both sides of the northern part of the North Atlantic, the most famous fishery being on the banks of Newfoundland. The Haddock (*Gadus æglefinus*) is another important species with a

similar range. It can easily be distinguished from the Cod by the black colour of the lateral line, and the presence of a rounded black patch just behind the gill cover. A third allied but smaller species is the Whiting (*Gadus merlangus*), the range of which is restricted to the seas of Northern Europe. It has a dark patch at the root of each pectoral fin and lacks the barbel of the two preceding species.

A small number of the species included in the Cod Family are fresh-water, and the best known of these is the Burbot or Eel-pout (*Lota vulgaris*), abundant in many of the rivers of North America and North and Central Europe. In England it is found in some of the rivers which flow into the North Sea. There are two dorsal fins, of which the second is very long and low, while on the under side of the body there is an anal fin of similar character. A barbel is present as in the Cod.

2. *Flat-Fish Family.*—The familiar food-fishes which make up this family are distinguished by a remarkable want of symmetry, which has no parallel among Vertebrates. One might at first sight imagine that the dark and light surfaces of the body were respectively upper and lower. A little closer inspection, however, would show that a long dorsal fin ran along one edge of the body and a long anal fin along the other; and further, that each surface had a lateral line running along it, and possessed both gill-cover and paired fins, thus conclusively proving the broad surfaces to be the sides. In some cases the dark upper side is the right one and in others the left. A flat-fish starts life with the same kind of symmetry as an ordinary fish, one eye being on the right and the other on the left, while the body is maintained in the usual position; but as development proceeds, and the body gets more flattened, one side becomes pigmented, and the eye of the contrary side is displaced so as to be near its fellow. We may take as well-known examples, Turbot, Plaice, and Sole.

The Turbot (*Rhombus maximus*) (fig. 34) is a large broad fish limited to European seas, and with the eyes on the *left* side. In the Plaice (*Pleuronectes platessa*), which though broad is a much smaller fish, the dark, eye-bearing surface is the *right* side. It is marked by large orange spots. This species ranges along the west coast of Europe and extends as far north as Iceland. The Common Sole (*Solea vulgaris*) also has the eyes

on the *right* side, but its shape is an elongated oval. It is confined to European seas.

Sub-order 5.—Tube-bladdered Fishes (Physostomi)

This large group (some 2500 species) includes many important food-fishes, and includes both marine and fresh-water forms as well as forms which, like the Salmon, live partly in the one and partly in the other. The fins are supported by soft jointed rays, except, in some cases, the first ray in the dorsal and pectoral, which may be transformed into spines. The pelvic fins are situated far back in what must be considered as the primitive position, judging by other orders of fishes. The air-bladder, which, as previously stated, is an outgrowth from the gut, always retains a connection with it by means of a tube, whence the name of the sub-order. Only the more important families can be mentioned here.

1. *Cat-Fish Family.*—The Cat-Fishes or Siluroids include a large number of species inhabiting the fresh waters of tropical and temperate regions, while some of them are estuarine or even marine, though in the latter case they do not go far from shore. The name "Cat-Fish" has reference to the presence of long barbels, suggesting to a lively imagination the "whiskers" of a cat. The scaleless body is sometimes protected by bony plates. There is only one European species, the Wels (*Silurus glanis*) (fig. 165), and this is limited to the rivers east of the Rhine. Excepting only the Giant Sturgeon, it is the largest of European fresh-water fishes, attaining a maximum length of 13 feet and weight of 400 pounds, though average specimens are very much smaller. In this species the skin is soft, and there are six barbels, two very long ones above and four much smaller ones below.

2. *Salmon Family.*—The members of this group are in the main either purely fresh-water in habit, or ascend rivers to spawn, and, with the exception of a New Zealand genus, are confined to the northern hemisphere. There are, however, a few purely marine species. The body is of the typical fish-form, and covered with scales, except in the head region. A fairly-large first dorsal is situated about the middle of the back, and much farther back there is a small second dorsal, which, on

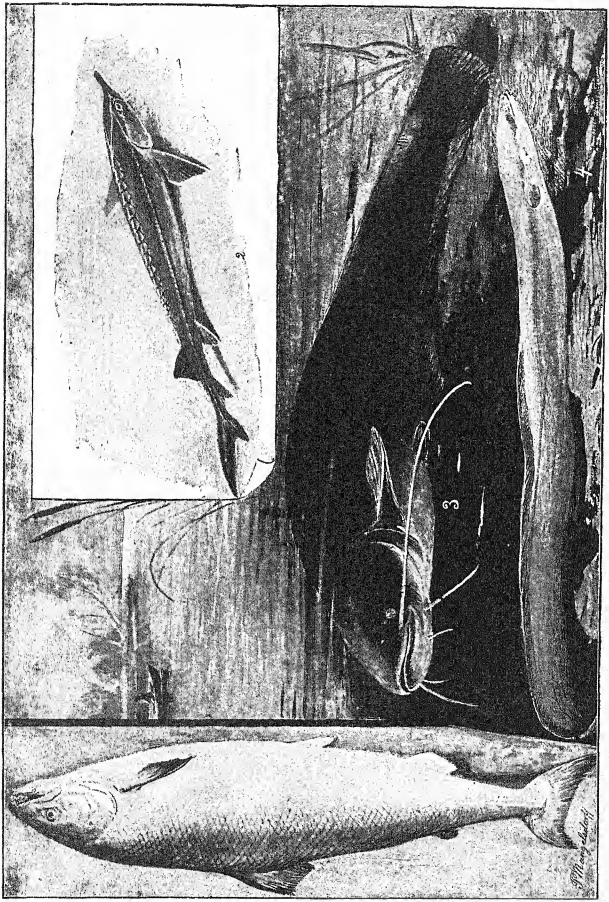


Fig. 165.—Group of Fishes reduced to various scales.

1, Salmon (*Salmo salar*). 2, Common Sturgeon (*Acipenser sturio*). 3, Wels (*Silurus glanis*.) 4, Eel (*Anguilla vulgaris*)

account of its fatty texture, is generally called the adipose fin. An anal fin is placed opposite or nearly opposite this.

The Salmon (*Salmo salar*) (fig. 165) ranges right round the northern hemisphere as far south as latitude 41° in the New World and 43° in the old. It is well known as one of the fishes that live partly in the sea and partly in fresh water, while the Common Trout (*Salmo fario*) is limited to the latter.

The Common Smelt (*Osmerus eperlanus*) is an example of the smaller members of the Salmon family. It is found in the seas of both Northern and Central Europe, as well as in some of the lakes and rivers of the same regions.

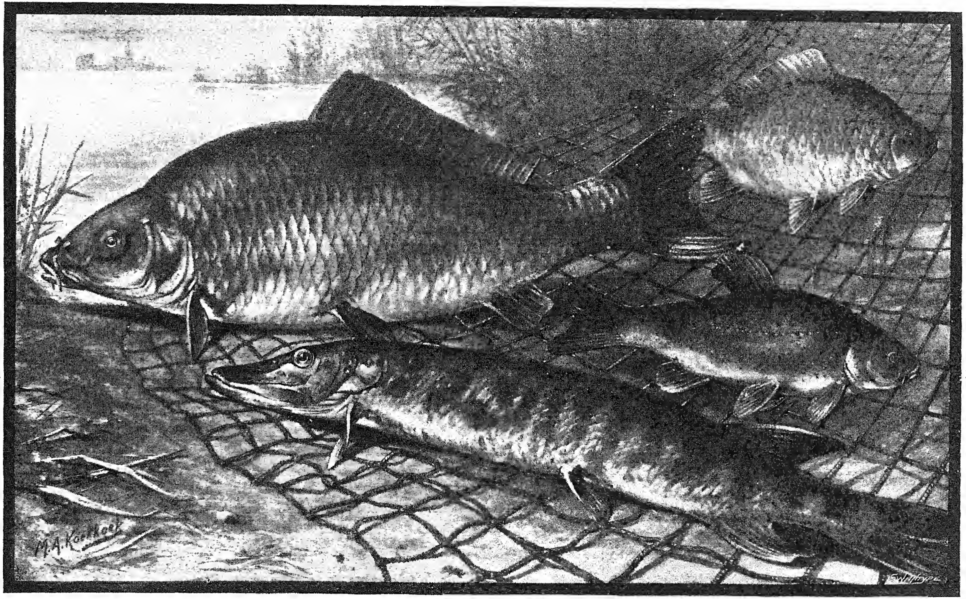
3. *Pike Family*.—This is a small group of predatory fresh-water fishes, including only seven species, of which six are confined to the United States, while the Common Pike (*Esox lucius*) has a wide distribution through the temperate regions of the northern hemisphere. There is no fatty fin, and the single dorsal is placed far back near the tail. The shape of the head, with its flattened snout and projecting lower jaw, is very characteristic.

4. *Carp Family*.—This is a large group of fresh-water fishes distributed through all the great land masses except South America and Australia. There is no fatty fin, and the mouth is entirely devoid of teeth, though these structures are present in the pharynx, attached to the bones which support the gill-arches. The Common Carp (*Cyprinus carpio*) is a stoutly-built fish with a long dorsal fin and two pairs of small barbels. It is a native of Asia, but, being much esteemed as food, was introduced into Europe at an early date, and is supposed to have been naturalized in this country by the monks during the Middle Ages. The well-known Gold-Fish (*Carassius auratus*) is a domesticated species of a genus of carps in which barbels are absent. It is a native of China and Japan, and the bright colouring is the result of artificial surroundings. Remarkable varieties of form have also been produced, as in other animals which have come under the influence of man.

Among native members of the family may be mentioned the Gudgeon (*Gobio fluviatilis*), a small fish with a pair of short barbels; the much larger Barbel (*Barbus vulgaris*), with four barbels; the Common Bream (*Abramis brama*); the Bleak (*Alburnus lucidus*), Roach (*Leuciscus rutilus*), Chubb (*L.*

GROUP OF FRESHWATER FISH

1. The Carp (*Cyprinus carpio*) inhabits ponds, lakes, and sluggish streams, living upon worms, insect larvæ, &c., and vegetable matter, to which food its thick-lipped mouth, provided with four sensitive barbels, is well adapted. It is very tenacious of life, and exceedingly long-lived (100 years or more). 2. The Crucian Carp (*Carassius vulgaris*) is a small fish common in the lakes and ponds of Central and Northern Europe. It is often kept in captivity, together with its near relative, the Gold-Fish, which is a domesticated variety of the Golden Carp (*C. auratus*). 3. The Tench (*Tinca vulgaris*) is a well-known ground-fish of the carp kind, and its food is of the same mixed nature. It lives in stagnant water, which may be so foul that no other fishes can maintain themselves in it. 4. The Pike (*Esox lucius*) is an exceedingly voracious fish, widely distributed through temperate North America, Europe, and Asia. It attains a very considerable size.



GROUP OF FRESHWATER FISH

1. The Carp (Cyprinus carpio).
2. The Crucian Carp (Carassius vulgaris).
3. The Tench (Tinca vulgaris).
4. The Pike (Esox lucius).

cephalus), Dace (*L. vulgaris*), and Minnow (*L. phoxinus*); Tench (*Tinca vulgaris*); and the Common Loach (*Nemachilus barbatulus*), a small elongated slimy fish, with mouth on the under side of the head and a fringe of six barbels round the edge of the upper jaw.

5. *Herring Family.*—The fishes of this family are mostly marine, and are found in the shallower parts of the sea all the world over in tropical and temperate regions. Although not distinguished by number of species, they are unsurpassed among fishes in the number of individuals, these often swimming together in vast shoals, which partly accounts for their very great commercial value. The body is of the typical fish-shape, and much laterally flattened, especially on the under side, which may form a sharp edge, often with a saw-like margin and sometimes supported by small bony plates. Fatty fin and barbels are absent. The head is naked, but the rest of the body is covered by thin glittering scales, which are easily detached.

The Herring (*Clupea harengus*) abounds in the North Atlantic, North Sea, and Baltic, and is also found in the Black Sea. The Pilchard (*C. pilchardus*) ranges from the Mediterranean round to the English Channel, and when young is the familiar Sardine. The Sprat (*C. sprattus*) abounds on the west coast of Europe and extends into the Baltic and part of the Mediterranean.

6. *Eel Family.*—The snake-shaped fishes belonging to this family have a wide distribution through both the seas and fresh waters of tropical and temperate regions. The pelvic and sometimes the pectoral fins also are absent, and the dorsal, caudal, and anal fins all form a continuous fringe. The skin is either entirely devoid of scales, or numerous very minute scales are imbedded in it.

The Common Eel (*Anguilla vulgaris*) (fig. 165) has pectoral fins and minute scales. It has a wide distribution throughout Europe, the countries bordering the Mediterranean, and North America. The large marine eel known as the Conger (*Conger vulgaris*) is found in almost all parts of the world, and is distinguished from the Common Eel by the entire absence of scales, and its large mouth armed with formidable teeth. The maximum length appears to be about 8 feet. The Mediterranean Muræna (*Muræna helena*) is the typical representative of a widely-distri-

buted section of marine eels. It attains the size of the Conger and was well known to the ancient Romans, who not only esteemed it as a delicacy but kept it as a pet. The skin is scaleless, as in the Conger, and is brilliantly coloured. The front end of the body is very thick, and the large mouth is armed with powerful teeth. Pectoral fins are entirely absent.

SUB-CLASS III.—SHARKS AND RAYS (ELASMOBRANCHII)

The Spotted Dog-Fish (*Scyllium canicula*) is a good type of this sub-class, and the description already given of it (pp. 257–264) will serve to give an idea of the essential features in the structure of the group. The most important of those features are the following:—The unsymmetrical tail, and position of the mouth and nasal openings on the under surface of the head. The possession of spiracular clefts and at least five pairs of gill-pouches, the external openings of which are not protected by a gill-cover. A cartilaginous skeleton, with comparatively simple skull and well-developed visceral skeleton, and paired-fin skeleton on the Dog-Fish type. Numerous rows of teeth on the margins of the jaws, constantly being renewed during life. A spiral valve in the intestine, and a cloaca. Well-developed arterial cone in the heart. A thick skin with placoid scales. No swim-bladder, or at most a small tubular outgrowth from the upper side of the gullet to represent it. Eggs large, containing much food-yolk.

It is convenient to divide these fishes into two orders, one containing the Sharks and Dog-Fishes (Selachoidei), the other Skates and Rays (Batoidei).

Order 1.—SHARKS AND DOG-FISHES (Selachoidei) (fig. 166)

The shark-like fishes of this order comprise about 150 species, distinguished by spindle-shaped bodies gradually tapering to the tail-end, which is sharply bent up. The gill-slits open on the side of the body, and the eyes possess lids. There are nine families, of which only seven need be mentioned.

1. *Blue Sharks*.—The type of this family is the Blue Shark (*Carcharias glaucus*), which often reaches the length of 15 feet. Though not uncommon in British seas during the warmer part of the year they are specially abundant in the tropics, like most

of the larger sharks. The Common Tope (*Galeus canis*) is a small shark with a very wide distribution, and is a well-known British species. It may attain a length of 6 feet or more, and in colour is dark grey above and white below. The body is slender and the snout prolonged and pointed. A somewhat

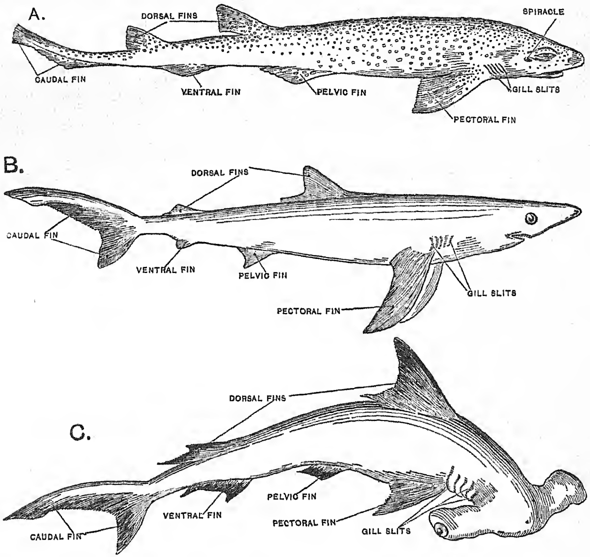


Fig. 166.—Sharks, reduced to various scales
A, Spotted Dog-Fish (*Scyllium canicula*). B, Blue Shark (*Carcharias glaucus*).
C, Hammer-headed Shark (*Zygæna malleus*).

smaller form, common in British seas and widely distributed over the world, is the Smooth Hound (*Mustelus lævis*), which can easily be distinguished from the Tope by its blunter snout, and the presence of whitish spots on the back. The most remarkable-looking member of this family is undoubtedly the Hammer-headed Shark (*Zygæna malleus*), in which, as the name indicates, the head is broadened out like a T by the presence of projections upon which the eyes are situated. It has occasionally been taken in

British seas, but cannot be considered as a native species, its habitat being the warmer parts of the ocean in almost all parts of the world.

2. *Porbeagles.*—This includes sharks, which are most abundant in the open ocean and are often of very large size. The pointed teeth are large and strong, and the gill-slits are usually very wide, while the spiracle is small or even absent. The Porbeagle (*Lamna cornubica*) is a North Atlantic form and fairly common on British coasts. It is about 10 feet long. The Thresher or Fox-Shark (*Alopecias vulpes*) is distinguished by the remarkable length of the upper lobe of the tail. It is abundant in the Atlantic and is the commonest large shark occurring on our coasts, but is also well-known in the Mediterranean, its range also including the coasts of California and New Zealand. The Basking-Shark (*Selache maxima*) of the North Atlantic may reach a length of over 30 feet. It is not uncommon on our western coasts. Unlike the last-named species, which does not attack man, the huge Rondeletian Shark (*Carcharodon Rondeletii*), which may attain the length of 40 feet, is universally dreaded. It is found in the warmer parts of the open sea in all parts of the world.

3. *Dog-Fishes.*—Of this the Spotted Dog-Fish, selected as our type (pp. 257–264), is a typical member. All are coast-fishes, found in most tropical and temperate seas. Another British species, closely resembling the preceding but of much larger size, is the Nurse Hound (*Scyllium catulus*). The Zebra Shark (*Stegostoma tigrinum*), common in the Indian Ocean, is a member of this family. It may be as much as 15 feet long, and receives its name from the characters of its markings, which consist of dark transverse bands on a yellowish ground.

4. *Spiny Dog-Fishes.*—The species belonging here are mostly of small size and are devoid of an anal fin. The gill-slits are small and a spiracle is present. The Piked Dog-Fish (*Acanthias vulgaris*) is common on the British coasts, and is characterized by the presence of a sharp spine in front of each dorsal fin. A much larger species is the Greenland Shark (*Læmargus borealis*), which inhabits the seas of the Arctic region, and is one of the worst enemies of the Greenland Whale, from the tail of which it bites large pieces. It sometimes strays as far south as Britain, and, though it may be as much as 15 feet long, is harmless to man.

5. *Angel-Fishes.*—This contains a single species, the Angel- or

Monk-Fish (*Rhina squatina*), found all over the world in tropical and temperate seas, and not uncommon on our western coasts. Its chief interest lies in its flattened shape, in which respect it may be regarded as an intermediate stage between the sharks and skates, and in the extremely large pectoral fins (the "wings" of the imaginary angel) which also afford a point of resemblance to the latter group.

6. *Port Jackson Shark Family.* — This is a small group of comparatively small forms, including only one genus of four species, of which two are found on either side of the Pacific. The best known is the Port Jackson Shark (*Cestracion Philippi*) which ranges from Japan south to Australia and New Zealand. The head is short and blunt, and there is a sharp spine in front of each dorsal fin; but the chief peculiarity is found in the teeth. Those in front are sharp-pointed, but the rest have blunt rounded crowns, and, being arranged in several closely adjacent rows, form a surface well adapted to crush the molluscs upon which the shark feeds.

7. *Comb-toothed Sharks.* — This is a small group of tropical and sub-tropical species possessing certain primitive characters. There is only one dorsal fin, and the gill-slits, instead of being five in number on each side, as in other members of the sub-class, are either six or seven. Four of the five known species belong to one genus (*Notidanus*), and one of them, the Grey Six-gilled Shark (*N. griseus*), an Atlantic and Mediterranean form, is sometimes taken in British waters. The teeth are elongated, and each of them consists of a series of slanting cusps diminishing in size from one end of the tooth to the other. The other three species of this genus have seven gill-slits on each side. The Japanese Frill-gilled Shark (*Chlamydoselache anguineus*), which inhabits very deep water, resembles an eel in shape, and its mouth is at the front end of the body instead of upon its under surface. There are six gill-slits on either side, and each of them is protected by a backwardly-directed fold of skin, pleated in a frill-like manner.

Order 2.—Skates and Rays (Batoidei) (fig. 167)

The Skates and Rays which constitute this group are much flattened from above downwards, just the reverse of what obtains

in an ordinary flat-fish, the breadth being increased by the enormous development of the pectoral fins, which form great wings extending from the head to the pelvic fins. As a result of this depressed shape, the gill-slits, of which the typical five pairs are present, are situated on the under side. The tail is narrow and forms a mere appendage, upon the upper side of which the small dorsal fins are placed, while the anal fin is absent. There are six families, of which five may be specially mentioned.

1. *True Rays.*—The numerous species of the rhomboidal-shaped fishes belonging to this family have a wide distribution, but are chiefly temperate forms more abundant in the northern than in the southern hemisphere. The numerous small teeth are closely packed in a considerable number of rows, arranged so as to form two roller-like surfaces which bite against one another. There are about twelve British species, of which the commonest are the Skate (*Raia batis*), in which the skin is comparatively smooth, and the Thornback (*Raia clavata*), which has the dorsal surface irregularly studded with large placoid scales of curious shape, each consisting of a circular disc from which a thorn-like spine projects, while a row of similar scales runs down the middle of the back.

2. *Saw-Fishes.*—This includes five species of fishes especially characteristic of tropical regions, and one of which (*Pristis antiquorum*) is common in the Atlantic and Mediterranean. The body is not broadened out to the same extent as in Rays, and in this respect is, so to speak, half-way between them and the Sharks. A remarkable peculiarity is found in the prolongation of the snout into a long flattened rostrum, in the sides of which are imbedded sharp teeth. These fishes may exceed 20 feet in length, as much as six of this being taken up by the "saw".

3. *Eagle-Rays.*—These are found both in tropical and temperate zones, one species, the Whip-Ray (*Myliobatis aquila*) being occasionally taken in British seas. The extremely slender tail is armed above with a strong spine, while the teeth, instead of being pointed, have flattened crowns, and are in contact with one another at the edges, so as to constitute a very perfect crushing surface, shaped like a roller.

4. *Sting-Rays.*—This group includes much-modified Rays, commonest in the tropics. The body is excessively broad, and the pectoral fins run forwards so as to surround the front of the

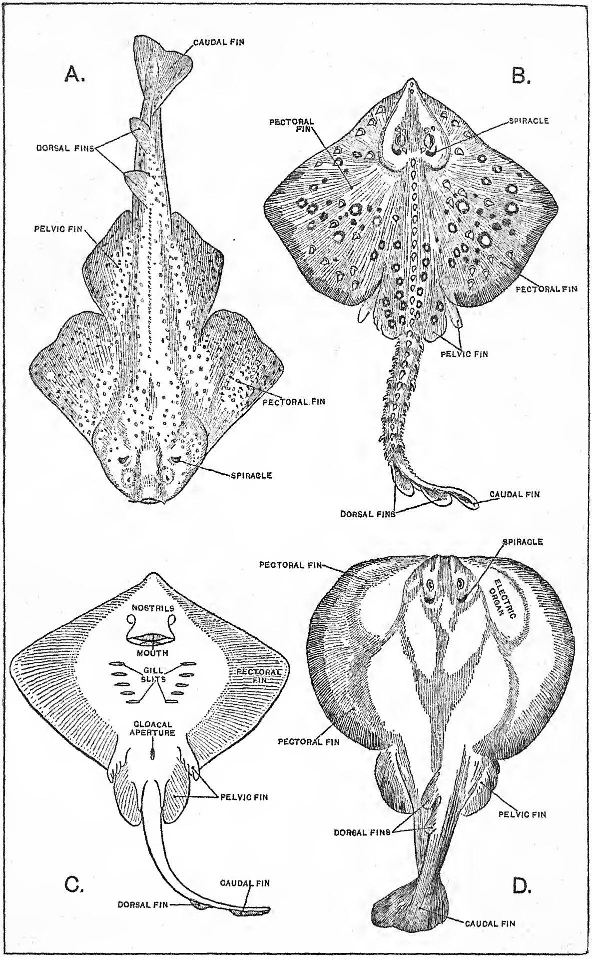


Fig. 167.—Monk-Fish and Rays, reduced to various scales

A, Monk-Fish (*Rhina squatina*). B, Thornback (*Raia clavata*). C, Under Side of young Skate (*Raia batis*) Electric Ray (*Torpedo nobiliana*).

head. The slender tail is usually armed with a formidable saw-edged spine, which is the so-called "sting". One widely distributed species, the Common Sting-Ray (*Trygon pastinaca*), is sometimes caught off the south of England.

5. *Electric Rays.*—In these the broad smooth body has a rounded outline, and on each side of the head there is an electric organ, capable of giving severe shocks. The most familiar genus, Torpedo, is represented by species in the Atlantic, Mediterranean, and Indian Oceans. A well-known Mediterranean form is the Marbled Torpedo (*Torpedo marmorata*), and an allied species is taken from time to time in British seas.

SUB-CLASS IV.—CHIMÆRAS (HOLOCEPHALI) (fig. 168)

This small sub-class, though related in many ways to the preceding one, is distinguished by a number of peculiarities. It includes only three genera of deep-water fishes. The best-

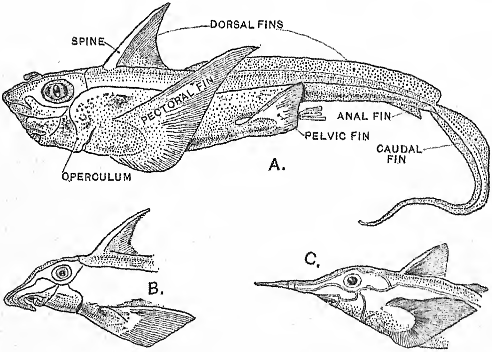


Fig. 168.—Chimæroids, reduced to various scales
A, Sea-Cat (*Chimæra monstrosa*), male. B, Bottle-nosed Chimæra (*Callorhynchus antarcticus*). C. *Harriotta*.

known form is the Sea-Cat or "King of the Herrings" (*Chimæra monstrosa*), the distribution of which includes the North Atlantic, Mediterranean, Cape of Good Hope, and Japan. In this animal the large head is rounded and the tail tapers to a mere thread. There is a powerful spine in front of the first dorsal fin, while in the male there is a peculiar tentacle-like

structure on the top of the head, armed with curved spines and capable of being drawn back into a pit. The eyes are very large and the skin is smooth. Only four gill-slits are present on each side, and they are covered over by a membranous flap or gill-cover. There is no spiracle. Another species of Chimæra is taken off the coast of Portugal, and the third is found on the Pacific coast of North America.

The Bottle-nosed Chimæra (*Callorhynchus antarcticus*) of the southern seas is more shark-like in form, and its name is derived from the curious thickened form of the snout. A third genus (*Harriotta*), recently discovered in very deep water both in the Atlantic and Pacific, is comparatively small and is distinguished by its slender-pointed snout.

SUB-CLASS V.—ROUND-MOUTHS (CYCLOSTOMATA)

The Lampreys and Hags which make up this sub-class are so unlike other fishes in many respects that many zoologists place them in a class of their own. They have a wide distribution

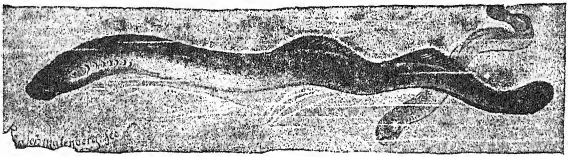


Fig. 169.—Lampern (*Petromyzon fluviatilis*)

in the temperate regions of both hemispheres, and the lampreys occur in fresh as well as in salt water. There are four British species, three of these being lampreys, any one of which will serve to illustrate the chief characters of the sub-class. They are the Sea-Lamprey (*Petromyzon marinus*), the River-Lamprey or Lampern (*P. fluviatilis*) (fig. 169), and the Small Lamprey (*P. branchialis*). The eel-like body is bordered by three narrow unpaired fins, two dorsals and a caudal, but all traces of paired fins are absent. Instead of possessing a slit-like mouth bounded by jaws, as in all the backboned forms so far considered, a rounded sucker-like concavity is present on the under surface of the head, and the small mouth opens within this. The scientific

name of the group is derived from this peculiarity (Gk. *kuklos*, a circle; *stoma*, a mouth). The skin is devoid of scales, but there are numerous little horny structures lining the mouth-sucker, and a muscular tongue armed with similar bodies can be protruded from the mouth and used as a rasping organ. A single nostril opens on the top of the head, behind this is the eye, and then come seven small round holes, which are the external openings of as many gill-pouches. The egg of the Lamprey develops into a larva which is so unlike the adult that it was formerly thought to be a distinct kind of fish and received the name of *Ammocœtes*.

The Common Hag-Fish (*Myxine glutinosa*) is shaped like a Lamprey, but the dorsal fin is absent, and the imperfect eyes are covered by the skin. The suctorial mouth is margined by eight barbels. At first sight there appear to be no gill-openings, but there are in reality six pairs of gill-pouches, the outer ends of which are drawn out below the skin into backwardly directed tubes, those on the same side uniting together and having a common opening pretty far back on the under surface of the body. The skin is very glandular, possessing the power of producing vast quantities of slime which sets into a firm jelly.

PRIMITIVE VERTEBRATES (Protochordata)

We now come to a number of very primitive forms, most of which were classified with the backboneless animals till comparatively recently. The characters of the backboned animals or Vertebrates have been enumerated and explained in an earlier part of this volume (pp. 60–63), to which reference must be made for details. It may, however, be remarked here that there are three chief characters by which a Vertebrate, or, to use a wider and better term, a Chordate, may be distinguished.

1. The possession at some period of life of a firm gelatinous rod, the *notochord*, running longitudinally below the central nervous system. Such a supporting rod can be made out in the embryos of all the forms hitherto described, but in most of them it is sooner or later squeezed out of existence, partly or entirely, by the development of a vertebral column. In some few instances,

however, as Lung-Fishes, Chimæra, Lamprey, and Hag, it persists throughout life, though invested in a firm sheath and supplemented by the development of cartilage. Ordinary bony fishes are a good instance of partial persistence of the notochord. Almost everyone must have noticed, in the pursuit of breakfast-table anatomy, that a gelatinous substance occupies the spaces between the doubly-cupped ends of the vertebræ in such fish as salmon and cod. This substance represents the part of the notochord which has not been nipped out of existence by the ingrowth of hard material to make up the joints of the backbone. In a Protochordate there never is a vertebral column or a backbone in the proper sense of the word, but only a more or less developed notochord.

2. It is scarcely less distinctive of Chordate animals that in them the pharynx should be perforated by visceral clefts in the embryo if not in the adult.

3. It is typical for a Chordate to possess a central nervous system (brain and spinal cord) situated *dorsally* above the notochord, and having the nature of a thick-walled *tube*.

We will apply these tests to the three recognized orders of Protochordates, *i.e.*: 1. Lancelets (Cephalochorda); 2. Sea-Squirts (Urochorda); and 3. certain still simpler forms grouped provisionally as Hemichorda. Very great theoretical interest attaches to the study of these forms, and much attention has been bestowed upon them, largely with a view of finding out how far they throw light upon the obscure problem having for its goal a determination of the characters of the simplest and earliest Vertebrates which appeared upon the globe.

Sub-class 1.—LANCELETS (Cephalochorda)

Lancelets are small fish-like creatures widely distributed round the coasts of the globe where the two conditions of sand and shallow water are combined. There are about 8 species, popularly referred to one genus *Amphioxus* (Gk. *amphi*, both; *oxus*, sharp), which, like the ordinary name, has reference to the fact that the flattened body is pointed at both ends. The common European species (*Amphioxus lanceolatus*) (fig. 170) is found on the Mediterranean and both Atlantic coasts, including our own islands. It is particularly abundant at Naples, where the

fishermen use it as bait. The translucent body varies in length from about 1½ inch to rather more than double that size, and at first glance one might be puzzled to say which was the front end of the body, as no distinct head is present. On closer inspection, however, a little hood-like structure, fringed by slender

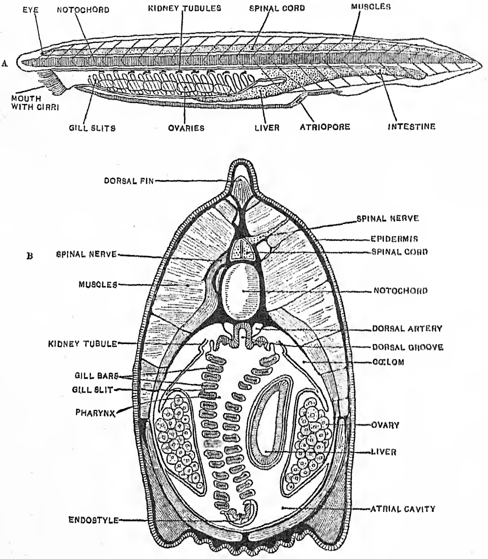


Fig. 170.—Lancelet (*Amphioxus lanceolatus*)

A, Side View, with internal organs seen by transparency. Semidiagrammatic. B, Transverse section. Much enlarged and semidiagrammatic.

tentacles, can be seen near one extremity. This marks the under side of the head end, and, since it leads to the mouth, has been called the *oral hood*, which has a certain resemblance to the mouth sucker of a Lamprey. Here as there jaws are absent, and the Lancelet is further devoid of the tooth-like projections and powerful rasping tongue which distinguish the Lamprey. Running along the upper margin of the body is a narrow *dorsal fin*, passing behind into a slightly expanded *caudal fin*, which again

is in one piece with a narrow *anal fin* running forward for a short distance. In front of this the under side of the body is broad, convex, marked by longitudinal pleats, and bounded on each side by a prominent fold which runs forwards to the oral hood. These two lateral folds converge behind and end where the anal fin begins. In the description of the Dog-Fish it was stated (p. 258) that the various unpaired fins are probably expanded surviving fragments of a continuous fin which, in ancestral forms, ran along the middle of the back, round the tail, and forwards for some distance along the under surface. Such a condition is actually represented by the Lancelet, for, as just stated, its unpaired fins constitute a continuous fringe to the body. But further, it is by no means improbable that the pectoral and pelvic fins of an ordinary fish represent the front and back ends of a continuous *lateral fin* which once existed on either side. There are no paired fins in the Lancelet, but the lateral ridges in front of the anal fin are perhaps equivalent to such continuous lateral fins.

The Lancelet is obviously segmented, *i.e.* divided into a number of similar successive parts from before backwards, and this segmentation is well seen in the muscles which make up a great part of the side of the body, these being divided up into >-shaped sections. At first view the animal looks as if it were bilaterally symmetrical, but this is not the case, for the muscle-segments do not correspond on the two sides of the body; and further, the external opening of the intestine (there is no cloaca) is placed on the left side of the body near the base of the tail-fin. There is also a lack of symmetry in other respects which need not be mentioned here.

A well-developed *notochord* is present, and like many of the other internal organs can be made out without dissection by examination of small specimens mounted whole as microscopic objects. There is, however, one peculiarity about it. Instead of stopping short about the middle of the brain, as it does in the higher Vertebrates, it runs to the extreme front, and the scientific name of the sub-class alludes to this (Gk. *cephalon*, head; *chordē*, string).

No *gill-slits* are visible on the exterior, but dissection shows that a very large number are present as oblique openings in the wall of the large pharynx. They do not, however, open directly

to the outside, but into a large *atrial cavity* which surrounds the pharynx, and which itself opens to the exterior by a rounded hole, the *atriopore*, on the under side of the body just in front of the anal fin. The state of things may be more clearly understood by reference to the development of the tadpole (p. 254), where the gill-slits at first open directly to the exterior but are

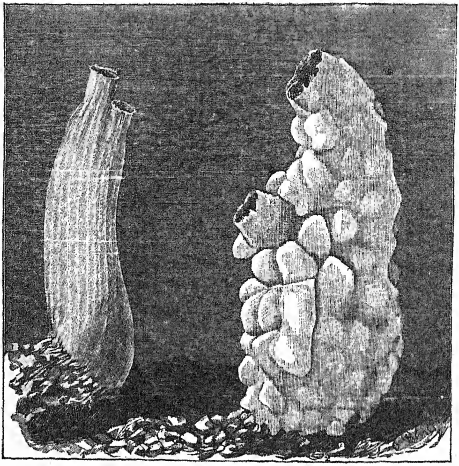


Fig. 171.—Two Simple Ascidians. 1, *Ciona intestinalis*. 2, *Phallusia mammillata*

later on covered over by the backward growth of a fold of the body-wall, the upshot of this being the formation of a branchial chamber into which the gill-slits open, and which opens to the exterior itself by a small hole on the left-hand side of the body. If this hole were in the middle line below, instead of on the left side, it might be compared to the Lancelet's atriopore, while the branchial cavity has much the same relations as the atrial cavity. It would probably be incorrect to consider the two cavities as closely equivalent, for they develop in very different manners.

The Lancelet will also stand the third test of a Vertebrate, for it possesses a tubular *nerve-cord*, situated above the notochord,

but not extending so far forwards. There is, however, no distinct brain.

It is usual to find this animal buried in the sand in a vertical position, with the head end projecting; but it can also swim, and is able to burrow in the sand with great rapidity.

SUB-CLASS II.—SEA-SQUIRTS (UROCHORDA)

Among the objects cast up by the tide on the sea-shore, or found attached to rocks which are uncovered at low-water, are certain leathery-looking objects which when touched emit a jet of water, a habit which has earned for them the name of *Sea-Squirts*. On account of the firm cover or tunic with which they are invested the name of Tunicates has also been widely used. They are the first fixed or sedentary animals with which we have had to deal, and this mode of life has had a profound influence upon their structure. A common British species, *Ascidia mentula*, may be taken as an example.

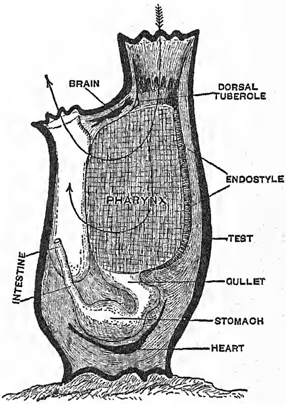


Fig. 172.—Diagram to explain structure of a simple Ascidian. The animal is seen from right side with dorsal surface to left and front end above. The arrows indicate course of water-currents which take food and oxygen into mouth, pass through perforations in pharynx into atrial cavity, and carry waste products to exterior through atriopore.

The plump rounded body is attached by one end to some foreign object, while at the other end may be seen two orifices (see p. 296, fig. 171), each placed on a projection, so as to give a distant resemblance to the skin bottles used in the East, and which is embodied in the name of Ascidians (Gk. *askos*, a wine-skin; *eidos*, like) often applied to these forms. One of the openings is situated at the extreme end and the other somewhat on one side. The former is the *mouth* and the latter the *atriopore*, and observation of a living specimen placed under water will show that currents set into one and out of the other. The protective tunic or *test*, which is thick and gristly in texture,

is interesting on account of its chemical composition, as it is largely made up of a substance, cellulose, which is almost entirely confined to plants. Dissection (fig. 172) fails to show the presence of a notochord, and the central nervous system merely consists of an elongated thickening or *ganglion*, placed about half-way between the two apertures, but the pharynx is perforated for breathing purposes as in ordinary Vertebrates. The mouth, in fact, leads into a large branchial sac or *pharynx*, perforated by innumerable small holes and suspended in an atrial cavity which opens by the atriopore already mentioned. There is therefore a general resemblance to the Lancelet in this respect, but in this case the intestine also opens into the atrial cavity.

Were we to rely only upon the anatomy of the adult we should hesitate before placing the Sea-Squirt among the Vertebrates, seeing that it conforms to only one of the three chief tests; but the matter is set definitely at rest by a study of the development. The egg of Ascidia becomes a tadpole-shaped *larva* in which a *notochord* is present, though it is confined to the tail, and for that reason is often called a urochord (Gk. *oura*, tail; *chordē*, string), which gives the name Urochorda, adopted at the head of this section as the name for the group of Sea-Squirts generally. And further, the ascidian tadpole is possessed of a hollow brain and spinal cord situated on the dorsal side of the body, besides which it may be noted that the perforations in the pharynx are at first of simple character, consisting of paired openings suggestive of the gill-clefts of fishes, &c.

After leading a free life for some time the tadpole attaches itself by means of adhesive projections situated at the head end, the tail with its urochord gets smaller and smaller and ultimately disappears, while the central nervous system is simplified into a single solid ganglion. We have, therefore, the remarkable phenomenon of an animal which, when young, possesses the distinctive vertebrate characters, but loses most of them in the adult condition, becoming, so to speak, of lower grade. This is a good example of biological *degeneration*.

It is a singularly interesting fact that one or two small free-swimming Ascidians, of which the best known (*Appendicularia*) (fig. 173) occurs in British seas, retain throughout life the tadpole

form and the typical Vertebrate characters. It is possible that these are primitive forms which retain the features distinctive of the ancestral Ascidians, but it is also possible that we have a case of animals which have dropped the adult stage out of their life-history, just as the Mexican Axolotls appear to be doing (see p. 249).

Ascidians may be divided into Fixed and Free-swimming forms, each of which groups can be again split up into Simple

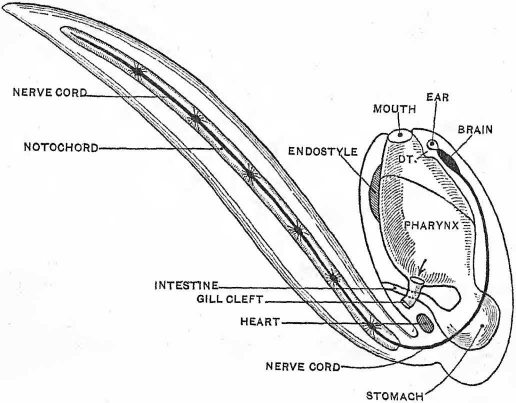


Fig. 173.—Diagrammatic drawing of Appendicularia (much enlarged), as seen from left side, with dorsal surface to right. D T, Dorsal tubercle.

and Colonial species. The last expression needs explanation, as it involves a phenomenon of which no instance is furnished by the animals previously considered. All these are propagated solely by means of eggs, but in Ascidians and many of the lower Invertebrates there may be increase by means of outgrowth of buds (gemmation) or by the bodily splitting (fission) of individuals to form others. As this suggests similar processes among plants, it is commonly known as *vegetative propagation.* A collection of animals which have been formed in this way, and which remain united together, constitute a *colony*, or are said to be colonial. In Ascidians colonies may be formed by means of budding.

The individuals of *Fixed Ascidians* are of comparatively large size in the Simple forms (fig. 171), of which the example taken is a typical one. The Colonial forms are made up of smaller individuals, and the colonies produced may be of the most varying form and size, while the degree of union between the members of the colony is more or less complete. In such a native genus, for instance, as *Clavellina*, we find a creeping stalk-like structure from which a number of individuals grow up, each of them being essentially similar to Ascidia. A good example of more intimate union is found in *Botryllus* (fig. 174), which can often be found at low tide as a bluish gelatinous crust upon stones and brown sea-weed. Imbedded in this are star-shaped groups of small individuals.

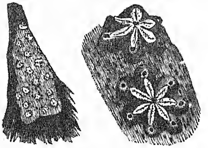


Fig. 174.—*Botryllus*

To left, a small colony, showing groups of individuals. To right, two groups of individuals, enlarged. The lower group is made up of seven members, with their mouths at outer ends. In centre is an atriopore common to all of them.

Among *Free-swimming Ascidians* the only Simple forms are Appendicularia (fig. 173) and its allies. The Colonial members include the remarkable phosphorescent *Pyrosoma*, which is shaped like a hollow cylinder closed at one end, and the *Salps*, of which more will be said elsewhere. Both are common in the Mediterranean.

Sub-class III.—WORM-LIKE PROTOCHORDATES (Hemichorda)

Here are massed together a small number of forms about which there has been endless discussion, and of which the one with most certain tenure of Chordate rank is a worm-like creature which has no common name, but which may perhaps be called the Acorn-headed Worm (*Balanoglossus*) (fig. 175). It is found at low-tide mark in many parts of the world, living in mud or sand which it glues together into a sort of temporary tube by means of a slimy fluid poured out from the skin. One species is found in the Channel Islands. The front of the body is made up of a swollen *proboscis*, yellow or orange in colour, and capable of altering its shape to a very great degree. It is attached behind by a narrow stalk, and the general outline in

some species suggests the term "acorn-headed". The *mouth* is situated on the under side, at the base of this proboscis. Next comes a comparatively short region, named from its appearance the *collar*, while the rest, and by far the longest part, of the animal may be termed the *trunk*. On the upper side of the trunk, behind the collar, are a considerable number of *gill-slits* arranged in pairs, and forming the external apertures of *gill-pouches* which communicate internally with the digestive tube. They resemble in many respects the corresponding structures in the Lancelet. A small *notochord* has also been identified, but here we have the opposite extreme from what is found in an Ascidian tadpole, for the structure in question is a small rod which projects into and supports the base of the proboscis. It is in reality a thickened forward outgrowth from the digestive tube, and has a peculiar microscopic structure which is distinctive of notochords wherever they are found. The fact that it grows out of the gut is also a point in support of its notochordal nature, for in more typical cases, as, *e.g.*, Lancelet or Frog, the notochord arises as a thickening in the wall of the digestive tube. The remaining test of a Vertebrate is also answered in a fairly satisfactory way, for what may be described as the *central nervous system* in this creature is a more or less hollow thickening running along the dorsal part of the body in the collar region.

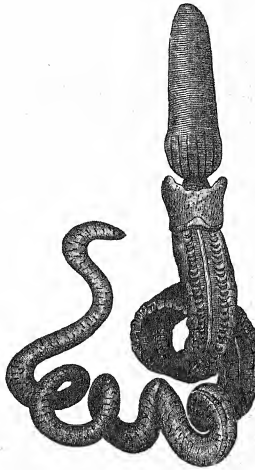


Fig. 175.—Acorn-headed Worm (*Balanoglossus*)

There are certain other more doubtful claimants to a place in the Hemichorda, but a discussion of their characters would be out of place in a preliminary sketch of the animal kingdom.

CHAPTER VII

BACKBONELESS ANIMALS (INVERTEBRATA). STRUCTURE AND CLASSIFICATION OF NEMERTINES AND MOLLUSCS

A brief account of the Backboned or Vertebrate animals has now been given, and in accordance with the usual custom from the time of Aristotle downwards all the remaining forms, far more numerous than they, may be conveniently lumped together as Backboneless animals or Invertebrates, divisible into a number of great groups or phyla, each of which is on a footing with the phylum Vertebrata. The lower Invertebrates are so unlike the Vertebrates that close comparison is not possible, but there are certain features which broadly serve to mark off a higher Invertebrate from a typical backboned animal. These are, to a large extent, implied in the summary given previously (pp. 60–63) of the chief Vertebrate characters, but it may be useful at this point to take such a form as a Cray-Fish or Lobster and point out the distinctive features in question (fig. 176).

The body of a *Lobster* has the same two-sided or bilateral symmetry as that of a Vertebrate, and there is a clear distinction between front (anterior) and back (posterior) ends, upper (dorsal) and lower (ventral) surfaces, and right and left sides. The body, too, is segmented, or divided into a number of similar parts from before backwards, as in, say, a Lancelet. This is evident in the Lobster's tail. It must not, however, be hastily assumed that a segment of a Lobster is the exact equivalent either of a Vertebrate segment or a segment in an Invertebrate from another group.

Now come a number of important differences. A large number of jointed *limbs* are present, arranged in pairs, while a Vertebrate has at most two pairs of limbs, though these may differ in nature in different animals, and in the simplest case, that of fishes, are unjointed fins. The limbs are modified for

various purposes. The most obvious are those which end in the large pincers, behind which four large pairs of walking-legs are apparent. Under the head are a number of overlapping limbs, turned somewhat forwards, which guard the mouth and act as jaws. In a Vertebrate the jaws are part of the bony framework of the head, helping to bound the mouth-cavity, and the lower jaw works up and down. But the limb-jaws of the Lobster are outside the opening of the mouth, and from the nature of the case work against one another from side to side. To realize this, raise your hands to your mouth and "clap" them together, which will give an idea of the way in which one pair of the Lobster's jaws are worked. Six pairs, however, are present in all.

By combining the knowledge obtained by dissecting one Lobster from the side and making a cross-section through another, the following distinctive characters of higher Invertebrates can be easily verified:—

1. There is a protective *external skeleton* (exoskeleton) but no internal skeleton (endoskeleton), *i.e.* nothing can be discovered equivalent to the skull, backbone, &c., of, say, a Perch, or to the notochord of a Lancelet. The absence of endoskeleton modifies the structure in many ways, as, *e.g.*, in regard to the attachment of muscles. In such a limb as the human arm the numerous muscles are attached to the bones, but in a Lobster's leg they are attached to the firm exo-skeleton.

2. The body is not a double but a *single tube* in structure.

3. The side-walls of the digestive tube are not perforated by gill-slits.

4. The *heart* is situated *dorsally*, the exact opposite of the Vertebrate condition.

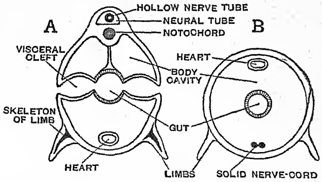


Fig. 176.—Diagrammatic Cross-sections through, A, a Vertebrate; B, a higher Invertebrate

5. The *nervous system* consists of a *ring* surrounding the gullet, and continued backwards into a *ventral nerve-cord.* The dorsal side of the ring is thickened into a double *brain* or *cerebral ganglion.* A very large number of Invertebrates possess such a nerve-ring and ventral cord, while many more have the ring

though not the cord. In no Invertebrate does the central nervous system consist, as in Vertebrates, of a hollow cord running along the dorsal side of the body.

The contrasts between a Vertebrate and a higher Invertebrate are illustrated by the accompanying diagrams (fig. 176).

The following groups or *phyla* of the Invertebrata are recognized. It must not be imagined, however, that they are anything like of equal size, for some are exceedingly large, while others are relatively small.

I. Nemertines (NEMERTEA).—Worm-like marine forms, which in some respects approach the Chordata in structure.

II. Molluscs (MOLLUSCA), including such forms as Cuttle-Fishes, Snails, Slugs, Oysters, and Mussels.

III. Jointed-limbed Animals (ARTHROPODA), the largest group of the animal kingdom, comprising such creatures as Insects, Scorpions, Spiders, and Mites; Centipedes and Millipedes; Shrimps, Lobsters, and Crabs.

IV. Segmented Worms (ANNELIDA).—A large group of forms, including innumerable Marine Worms (free-living and tube-inhabiting), Earth-Worms, Fresh-water Worms, and Leeches.

V. Siphon-Worms (GEPHYREA).

VI. Wheel Animalcules (ROTIFERA).

VII. Moss-Polypes and Lamp-Shells (MOLLUSCOIDA).—The great bulk of these are fixed marine animals, and those belonging to the first group are nearly all colonial.

VIII. Flat-Worms (PLATYHELMIA).—The most familiar of the forms grouped here are the Flukes and Tape-Worms, which are found as parasites within the bodies of other animals.

IX. Thread-Worms (NEMATHELMIA).—The name of the group indicates the shape of these creatures, most of which are parasites, either in plants or else within the bodies of other animals.

X. Echinoderms (ECHINODERMATA).—This phylum is constituted by such marine forms as Star-Fishes, Sea-Urchins, Sea-Lilies, and Sea-Cucumbers.

XI. Zoophytes (CŒLENTERATA).—Mostly marine animals, which may be either simple or colonial, fixed or free-swimming. Familiar examples are Jelly-Fishes, Sea-Anemones, and Corals.

XII. Sponges (PORIFERA).—Mostly marine, colonial, and fixed.

XIII. Animalcules (PROTOZOA).—This lowest phylum includes an immense number of simply-constructed animals, which are nearly always very small or microscopic in size. They are found almost everywhere, but are unfamiliar to those who are not in the habit of using the compound microscope.

A brief survey will now be made of these thirteen phyla, but many particulars regarding them will be found in other parts of this work.

NEMERTINES (Nemertea)

Although the worm-like forms which belong here have a wide distribution, and are particularly common between tide-marks on almost all coasts, they are nevertheless practically unknown except to the professed naturalist, and have received no common names. There are some forty British species. The vast majority are marine, and either shore or shallow-water forms, but they are also represented in fresh water and even on land. They have been given here the first place among Invertebrates, in deference to the views of many zoologists, in whose opinion they come near to the Protochordates.

The body of a typical Nemertine (fig. 177) is cylindrical, and presents no trace of segmentation. It may be only a small fraction of an inch in length, or in other cases many yards long. A common British form (*Lineus marinus*) is one of the species which are extremely elongated, and it may not infrequently be found under stones, with its slimy black body twisted up into a complicated coil. Other species may be more or less brightly coloured.

The *mouth* is a small oval opening on the under side of the head end, while the aperture of the intestine is at the extreme tip of the tail. Close examination will show that above the mouth on the front end of the body there is a small pore, and in a living specimen a narrow thread may sometimes be seen to shoot out from this pore, through which it can again be drawn back into the body. This thread is known as the *proboscis*, and, as described elsewhere, it is used as a means of killing or paralysing the marine worms upon which a Nemertine chiefly feeds. When within the body it is enclosed in a special sheath which overlies the digestive tube. The proboscis is hollow, and the way in which it is protruded and again drawn back may be understood by taking the somewhat hackneyed illustration of a glove with one finger. If this finger be pulled back into the main glove by turning it outside inwards, we shall have a rough model of the proboscis when lying within the body.

If now the finger be pushed out, it will represent the extended proboscis. The pulling in is effected by means of a muscle band which runs along the interior of the thread and is attached to its tip, while the pushing out is the result of fluid being squeezed into the thread from its sheath. This kind of principle is utilized elsewhere in the animal kingdom, and a very familiar example

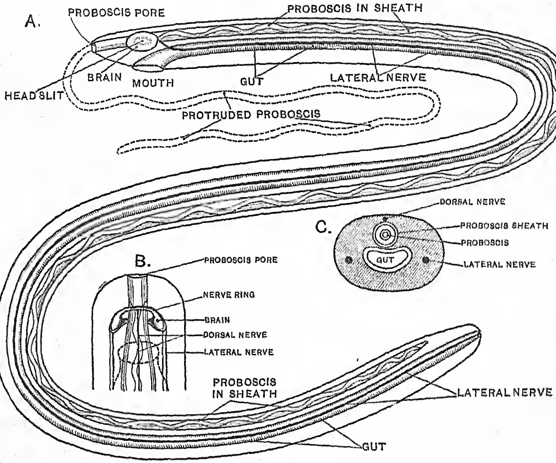


Fig. 177.—Structure of a Nemertine (diagrammatic)

A, Side view, internal organs seen by transparency. B, View from above of front end; position of mouth and beginning of gut indicated by the dotted line. C, Cross-section.

is found in the "horns" of the common Snail, which can either be stretched out (as immortalized in the nursery rhyme wherein the adventures of certain snail-hunting tailors are set forth) or withdrawn into the body at will.

Reasons have been adduced for thinking that the proboscis-sheath is comparable to a notochord, and the proboscis to a curious little structure attached to the under side of the brain in Vertebrates, and known as the pituitary body.

The *central nervous system* of a Nemertine is interesting in many ways. It consists of a *nerve-ring*, which encircles the front end of the proboscis, and not the digestive tube as is usual among

Invertebrates. Each side of the ring is thickened into a ganglion, from which a lateral nerve-cord runs along the corresponding side of the body, while there is a much more slender nerve running back in the middle line above from the upper side of the ring. This *dorsal nerve* has attracted a great deal of attention, for it has been compared to the spinal cord of a Vertebrate, though, unlike this, it is solid.

MOLLUSCS (Mollusca)

Molluscs include such familiar shell-fish as Periwinkles, Oysters, Cockles, and Mussels, as well as soft-bodied animals like Cuttle-Fishes, to which the term Mollusca (Lat. *mollis,* soft) was originally applied.

Examination of such a typical form as the Ormer or Sea-Ear (*Haliotis tuberculata*), which is common in the Channel Isles, will give some idea of the characters of Mollusca in general, and of the special subdivision to which this particular sea-snail belongs (fig. 178).

External Characters.—The most obvious feature is the presence of a large external *shell* covering the upper side of the body, from which it cannot be detached without cutting through a large rounded fleshy mass, the *shell-muscle.* The shell is not symmetrical, for a row of holes can be seen running along near its left margin, and on the right side at the back a spiral twist can be made out. Turning the animal over, a huge fleshy mass with a flattened surface is seen projecting from the under side of the body. By means of this *foot* the Ormer is able to adhere to rocks like a Limpet, and to crawl about like an ordinary Snail. A foot in some form or other is characteristic of all Mollusca, and it must be understood that the word is here employed with a special meaning of its own. Projecting in front from above the foot a short *head* can be seen bearing a blunt snout, at the end of which the *mouth* is placed, and a pair of pointed feelers or *tentacles*, which are solid, and cannot therefore, like those of a common Snail, be withdrawn into the body. Seen from below, the body of the Ormer is bilaterally symmetrical, and the twisted condition of its upper part is a special condition characteristic of snail-like forms in general.

On removal of the shell by cutting through the shell-

muscle the soft upper part of the body in which a large part of the viscera are contained will be exposed, and it will be noticed that this *visceral hump*, as it has been called, is twisted behind in correspondence with the twist in the shell. Skirting the visceral hump is a flap, produced by a pulling out, so to speak, of the body wall, and known as the *mantle*. In the Ormer it is narrow for most of its extent, but is very well developed in the part underlying the row of holes in the shell, where it roofs in a large *mantle-cavity*, which has a long slit-like aperture above and a wide opening in front about the head. That this mantle-cavity should freely communicate with the exterior is very necessary, for not only does it contain the breathing organs, but the intestine and the kidneys open into it. A very small amount of dissection reveals the presence of the breathing organs in the form of two plume-like *gills* attached along their sides, and having their tips pointing forwards. The projecting end of the intestine will also be seen, and right at the back of the cavity two small holes by which the kidneys open.

Just behind the mantle-cavity the *heart* is situated, consisting of a central *ventricle*, which pumps purified blood from the gills through *arteries* which come off from it fore and aft, and of a thin-walled *auricle* on either side. The ventricle is folded round the intestine, a noteworthy peculiarity, though one not known to have any physiological meaning. A heart like this, which contains pure blood only, is said to be *systemic*, and it should be noted how markedly it differs from the heart of an ordinary fish, which contains impure blood only. The complex heart of a Bird or Mammal is physiologically equivalent to both these varieties of heart, for its right half receives impure blood and pumps it to the breathing organs, while its left half is concerned with the reception of pure blood from those organs, and the distribution of the same to the general system.

The *digestive organs* of the Ormer consist of a long digestive tube with large glands opening into it, and including pharynx, gullet, stomach, and intestine, the last, as already noted, ending in the mantle-cavity. Particular interest attaches to the *pharynx*, or buccal mass, which is partly modified into a complex *rasping organ* (odontophore), characteristic of two great groups of the Mollusca. It essentially consists of a rounded cushion rising from the floor of the pharynx, over which is stretched from front to

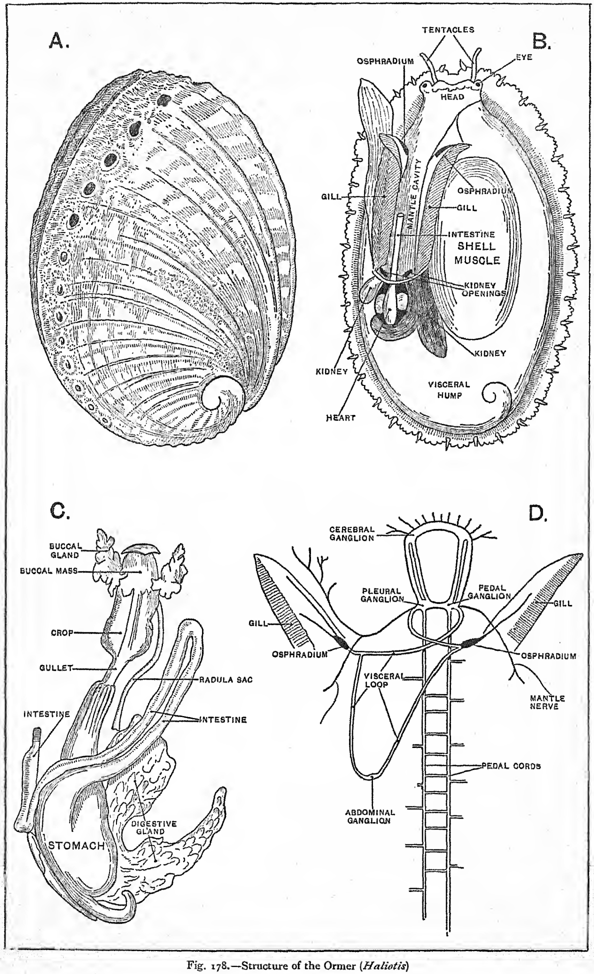


Fig. 178.—Structure of the Ormer (*Haliotis*)

A, Shell from above. B, Semidiagrammatic view from above after removal of shell. The roof of the mantle-cavity has been cut away and the heart exposed. The small left kidney (unshaded) and hinder part of large right kidney (shaded) shown by transparency. C, Digestive organs. D, Diagram of nervous system.

ɔack a horny ribbon, the *radula*, beset with transverse rows of linty teeth. This ribbon, often called the "tongue" or "palate", ıas often been compared to a finger-nail, and as worn away it constantly grows forwards from a projection (radula sac) at the ɔack of the pharynx, just as the finger-nail does from its root. A fuller account of this organ will be given in another place.

The *kidneys* of the Ormer are two irregular brown bodies, ɔpening as described. The left one is very small, and would seem not to act as a kidney at all.

There are certain characteristic features of the *nervous system* which require notice. It consists of a *nerve-ring* surrounding the ɔeginning of the digestive tube, and of other connected parts. The upper part of the ring consists of a transverse band conıecting two swellings, the *brain* (or cerebral) *ganglia*, and from each of these two cords run downwards to constitute one side ɔf the ring. The outer cords end below in a pair of *lateral* (or pleural) *ganglia*, and the inner cords in a pair of *foot* (or ɔedal) *ganglia*, which are united together in the middle line so ıs to complete the ring below, while each lateral ganglion is ılso connected with the adjoining foot ganglion. From the ɔrain ganglia, nerves run off to the sensitive parts of the head ncluding the tentacles, and strong nerves to the foot run backwards through the substance of that organ from the foot ganglia. There still remains to be described a *nerve-loop*, which connects he two lateral ganglia and gives off nerves to some of the nternal organs. It is a nerve-cord which, starting from one ateral ganglion, runs obliquely backwards, and, turning round in ı curve at the level of the hinder end of the mantle-cavity, weeps forwards again and takes an oblique course to the other ateral ganglion, taking altogether a course which may be compared o the figure 8. Three ganglia are seen as swellings upon this oop, one close to each gill, and the third at the back end of he 8. The curious course of the loop is one result of the wisting of the body which has affected both the visceral hump ınd shell.

The most important organs of sense are the *tentacles*, which ıave to do with touch, so-called *organs of hearing*, consisting ıf a pair of little rounded sacs attached to the foot ganglia, nd two small cup-shaped *eyes*, one at the base of each tentacle. There is also a special sense-organ connected with each gill,

which is generally considered a kind of organ of smell, entrusted with the duty of testing the quality of the water which enters the pallial cavity. It is termed the *osphradium.*

The preceding account of the Ormer illustrates the most prominent characters of Mollusca generally, which are: (1) the absence of segmentation, (2) the presence of a *mantle*, (3) the muscular *foot*, (4) the systemic *heart*, (5) plume-like *gills*, and (6) a *nerve-ring* surrounding the first part of the digestive tube. The vast majority of Molluscs either possess all these characters or else a sufficient number of them to leave no doubt as to how they should be classified. Other very common, though by no means universal, characters of the group are the presence of a *shell* and development of a *rasping organ* (odontophore). Large numbers of Molluscs are also distinguished by the bilateral symmetry of their bodies, and though the Ormer is not one of these, it is, as already pointed out, symmetrical so far as the lower half of the body is concerned.

Five classes are recognized among Mollusca, as follows:—

1. Head-footed Molluscs (CEPHALOPODA), including the Pearly Nautilus, Cuttle-Fishes, Squids, and Octopi.
2. Snails and Slugs (GASTROPODA).
3. Bivalve Molluscs (LAMELLIBRANCHIA), including forms with the shell in two pieces, *e.g.* Oyster, Mussel, and Cockle.
4. Tusk-shells (SCAPHOPODA).
5. Proto-Molluscs (AMPHINEURA), a small group of which the only common member is Chiton, distinguished by the possession of eight overlapping shelly plates on the upper surface of the body.

CLASS I.—HEAD-FOOTED MOLLUSCS (CEPHALOPODA)

As a good type for description we may select the Common Cuttle-Fish (*Sepia officinalis*), one of our native species, which preys upon fishes and crustacea in shallow water, and is a free-swimming form (fig. 179).

External Characters.—The body is bilaterally symmetrical, and at one end of it the *mouth* may be seen, provided with a pair of horny *jaws* resembling those of a parrot, and surrounded by ten arms or *tentacles*, of which two are very long and can be drawn back into special pouches. The inner sides of the eight short arms are studded with adhesive *suckers*, and each long arm swells at its end into an oval pad, one side of which is

similarly provided. Outside the circlet of arms a large *eye* can be seen on either side, covered by a circular eyelid perforated by a small hole. The presence of mouth and eyes shows that we are dealing with the head end of the animal. In comparing the body with that of the Ormer we must place this end downwards and slant the rest of the animal, which is mostly visceral

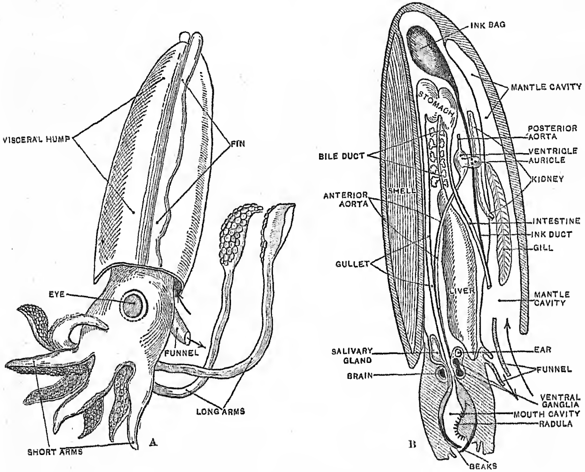


Fig. 179.—The Cuttle-Fish (*Sepia officinalis*) reduced
A, View from left side. B, Side-dissection. Arrows show course of water into and out of mantle cavity.

ıump, upwards and backwards as shown in the diagram (A). It will then be clear that the long axis of the body is pretty nearly ıt right angles to the direction corresponding to the long axis n the Ormer. The long *visceral hump* will possess two gently-curved sides facing respectively forwards and backwards, and wo sharp edges placed right and left and margined by a fin-like expansion. The next point will be to find mantle and foot. The ormer is readily made out running round the edge of the large visceral hump at its lower end, just above a narrowed "neck" ndicating the boundary of the head. Most of it is at the back, vhere it constitutes the hinder wall of a large *mantle-cavity*, nto which a large slit-like opening leads. The *foot* has grown

round the head, and chiefly consists of the ten arms or tentacles. It is from this peculiarity the name of the class is derived (Gk. *kephalon*, a head; *pous*, a foot). Just above the back of the head, and projecting from the opening into the mantle-cavity, will be noticed a muscular conical tube, the *funnel*, by the ejection of water through which the Cuttle-Fish is able to swim rapidly backwards. It will be observed that the mantle-cavity is here at the back, while in the Ormer it is in front, one result of the twisting which the visceral hump of that animal has undergone. In its natural position, whether resting on the sea-bottom or swimming, the front side of the head and visceral hump is directed upwards, and this side is much darker than the other. It may be taken as a general rule that the surface of an animal habitually facing in this direction is the darkest part of the body, though its actual nature varies in different animals. Here it is the front side, but in a Dog-Fish it is the true upper or dorsal side, and in a flat-fish either the right or left side according to the species (see p. 279). One peculiarity of the Cuttle-Fish's skin is especially noteworthy. If a living specimen is watched, it will be seen that beautiful purplish flushes of colour sweep over the body from time to time, leaving it comparatively pale in the interval. The cause of this is to be sought in the presence of innumerable little rounded *colour-bodies* (chromatophores), which, under the control of the nervous system, vary in size. When reduced to their smallest dimensions the skin is pale, but when fully expanded it is dark. A similar phenomenon has been described for the Frog (p. 251), where, however, the colour changes are comparatively slow.

Cutting open the mantle-cavity, we shall find similar parts and openings to those described for the Ormer (p. 308). In the middle line there is the projecting end of the intestine, and on either side of this a kidney aperture, while a plume-like *gill* is to be seen on either side. As is well known, the Cuttle-Fish and many of its allies are able to eject an inky substance into the surrounding water as a means of protection. This ink is formed within a rounded *ink-bag*, and carried off through a slender tube which has a common external opening with the intestine.

The front side of the visceral hump has imbedded in it a broad "cuttle-bone", composed of overlapping layers of cal-

careous material. This is to be regarded as a *shell*, and is not internal in the same sense as the internal skeleton of a Vertebrate, for it is inclosed in a pouch of the skin which has lost the opening to the exterior probably possessed by ancestral forms. Some Molluscs still exist in which the shell is almost but not quite covered by folds of the skin which have grown over it.

As regards the internal structure of the Cuttle-Fish, it need only be remarked that there is a very large *rasping organ* (odontophore); a systemic *heart*, consisting of a ventricle and two auricles; and a *nerve-ring*, swollen into very large ganglia and protected by a cartilaginous case.

The eggs are enclosed in oval cases which are united together into masses, that have been compared to bunches of grapes in appearance, and which are among the common objects cast up on the sea-shore.

Cephalopods are divided into two sub-classes, named, according to the number of gills: 1. Dibranchiata (Gk. *dis*, twice; *branchia*, gills), of which the Cuttle-Fish is an example; and 2. Tetrabranchiata (Gk. *tetra*, four; *branchia*), of which the only living representative is the Pearly Nautilus.

Sub-class 1.—CUTTLE-FISHES (Dibranchiata)

This sub-class is again divided into two groups, *Decapoda* with ten arms, and *Octopoda* with eight. The former includes the Cuttle-Fishes, of which Sepia is a type, the Squids, and Spirula. Squids, or, as they are sometimes termed, Calamaries, have an even wider distribution than Cuttle-Fishes, for they are not only found in coastal waters, but are also pelagic, *i.e.* living in the open sea, where shoals of them are met with. A common Atlantic and Mediterranean species which abounds on our shores is the Common Squid (*Loligo vulgaris*). This animal is of more slender build than the Cuttle-Fish, and a large triangular fin projects from each side. The shell or "pen" is a narrow horny structure, shaped like a lance-head. The old name Calamary for creatures of the kind was given in allusion to this "pen" (L. *calamus*, a quill), its shape being compared to a short quill.

Some of the Squid family attain gigantic dimensions, and there can be little doubt that specimens of the kind are largely responsible for the numerous tales and legends which

exist regarding a supposed marine monster, the Great Sea Serpent, or Kraken. Actual measurements which have been made from time to time of bodies or portions of the bodies of such creatures leave no doubt that a total length of over 50 feet may be attained, the greater part of this, however, being taken up by the long arms. Gigantic Squids of the kind are sometimes cast ashore on the western coasts of Britain among other localities.

Spirula (Fig. 180) is a small animal in which the shell is spiral and divided into numerous chambers by transverse partitions. It is partly enclosed in folds of the skin. The animal itself is but rarely met with, though its shells are common on Pacific shores and may be seen in most museums.

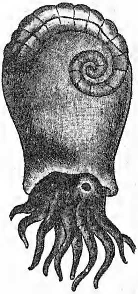


Fig. 180.—Spirula

The *Octopods*, or 8-armed Cephalopods, differ from the Cuttle-Fishes and Squids in the absence of the two long arms, besides which they are entirely devoid of an internal shell. The visceral hump is short and rounded, and the suckers on the arms are unstalked. The group includes the Octopi and their allies, and the Paper Nautilus or Argonaut.

The Common Octopus (*Octopus vulgaris*) is common on rocky shores on the margins of both Atlantic and Mediterranean, lurking in crevices, crawling by means of its sucker-studded arms, or swimming swiftly backwards like the Squids. Each arm is provided with two rows of suckers, while in an Octopod, common on British coasts, *Eledone moschata*, there is only one. The specific name of this particular species, which is eaten by the Italians, has reference to the strong musky odour of the animal.

Some Octopods attain a very large size, though they are inferior to Squids in this respect. Large specimens are reputed to be common on the shores of the island of Sark in the Channel group, and a well-known description of an imaginary combat with one of these is given in Victor Hugo's *Toilers of the Sea*.

The Argonaut or Paper Nautilus (*Argonauta argo*) is a pelagic form, common in the Mediterranean, in which the female is provided with a thin cap-shaped shell, which is symmetrical, and

large enough to contain the entire body of the animal. It is mainly secreted by the inner surfaces of two of the arms, which are dilated at their ends into large lappets. By means of these the animal holds on to the shell, which is not attached to it by any muscular or fibrous tissue.

Sub-class 2.—PEARLY NAUTILUS (Tetrabranchiata)

The only living representative of this is the Pearly Nautilus, of which the best-known species (*Nautilus pompilius*) (fig. 181) has a wide distribution in the Indian and Pacific Oceans. The animal is enclosed in a large spiral shell, of which the coiled-up portion projects forwards towards the animal's front end. The body does not occupy all the shell, for a considerable part of this is divided into a series of gas-containing chambers by means of curved partitions, concave towards the external aperture. The last and broadest part forms a body-chamber in which the animal is contained, the rounded end of its visceral hump resting against the concave surface of the last partition. The shell grows in size by successive additions to its aperture or mouth in accordance with the growth of the animal, and at the same time the older part of it is from time to time cut off by formation of a new partition, the body slipping forwards, as it were, so as to permit of this. The old chambered part of the shell is not, however, entirely devoid of soft parts, for each partition is perforated in the middle by a hole continuous with a short tube directed away from the body-chamber, and in this way a hollow structure know as the *siphuncle* is constituted,

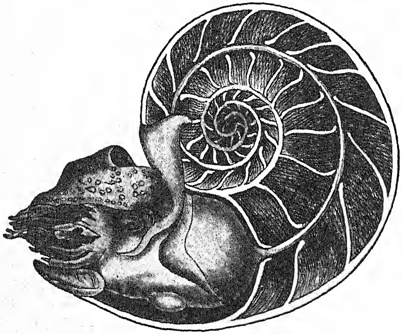


Fig. 181.—Pearly Nautilus (*Nautilus pompilius*). The left half of its shell has been removed

which is traversed by a fleshy cord, continuous almost like a tail with the rounded end of the visceral hump. This is also connected with either side of the body-chamber by means of a broad shell-muscle. The shell consists of an external membrane exhibiting brown and white marking, a white porcelain-like layer, and an internal layer possessing a beautiful pearly lustre, the appearance of which has suggested the ordinary name of the animal.

The *foot* is not constituted by long tentacles or arms as in the Cuttle-Fishes, &c., but consists of a number of lobes upon which are borne a large number of slender adhesive tentacles, the tips of which can be drawn back into sheaths. A *funnel* is present as before, but instead of being a complete tube it is made up of two halves which are rolled upon each other. Within the mantle-cavity, which occupies the same relative position as in a Cuttle-Fish, there are four instead of two plume-like gills, and in correspondence with this the heart has four auricles, one for receiving the purified blood from each gill, and there are four instead of two kidneys. The *eye* is of extremely simple structure, and has been compared to a pin-hole camera, consisting as it does of a deep cup, which would be closed externally were it not for the presence of an extremely small rounded aperture like a pin-hole.

Class 2.—SNAILS AND SLUGS (Gastropoda)

The Ormer already described (pp. 307–311) belongs to this class, that includes a very large number of species, of which the vast majority are distinguished by the presence of a head bearing tentacles, a flattened creeping foot, and a shell which consists of only one valve or piece, and is therefore said to be *univalve.* The class is split up into smaller divisions as follows:—

Sub-class 1.—Streptoneura (Prosobranchia).

Order (1). Comb-gilled Snails (Ctenobranchia).
Order (2). Shield-gilled Snails (Aspidobranchia).

Sub-class 2.—Euthyneura.

Order (1). Hind-gilled Snails (Opisthobranchia).
Order (2). Lung Snails and Slugs (Pulmonata).

Sub-class 1.—STREPTONEURA (Prosobranchia)

This subdivision of Gastropods is partly founded on the course taken by the nerve-loop which is attached to the nerve-ring. It is here twisted, as, *e.g.*, in the Ormer (see p. 310), into a shape resembling the figure 8. Another important feature is afforded by the gill or gills which, when present, are in front of the heart, as again in the Ormer (see p. 308). These Molluscs may therefore be termed "fore-gilled" or *prosobranch* (Gk. *pro*, in front of; *branchia*, gills). They include most of the marine snails which are to be found on the sea-shore. On the shape of the gills, among other characters, the two orders of the sub-class are marked off from one another, *i.e.* (1) *Comb-gilled Snails*, with a single gill consisting of an axis bearing a series of small flattened plates, comparable to the teeth of a comb; and (2) *Shield-gilled Snails*, in which there are two series of such plates, one on each side of the gill-axis. In some members of the second order two gills are present.

Order (1). *Comb-gilled Snails* (Ctenobranchia).—This order is divided into no less than fifty-nine families, so that space will prevent more than a brief notice of a few common forms.

Probably no sea-snail is more familiar than the Periwinkle (*Littorina littorea*), common on the rocks between tide-marks, and illustrating a number of points in which the members of the order differ from the Ormer and related forms. The thick rounded shell is obviously spiral, and the visceral hump it covers is of the same shape. The spiral, as in most snails, is a right-handed one, *i.e.* with its turns running in the same direction as an ordinary screw or corkscrew, so that if the shell be placed on end with apex above, its turns or whorls will be seen to slope up from left to right. The most primitive Molluscs known are bilaterally symmetrical, devoid of a prominent visceral hump, and with a posterior mantle-cavity into which the intestine, &c., open. Such spirally-twisted forms as Periwinkle have apparently arisen from simple forms of the kind by development of a visceral hump, together with a strong shell to cover it, and also to serve as a shelter into which the animal might withdraw itself. At the same time twisting took place, perhaps as a result of the weight of the parts, and the result has been that mantle-cavity, end of intestine, gills, heart, and kidneys have been brought

round to the front (fig. 182). It is at any rate pretty clear that a spiral hump and shell are more compact and convenient than a much elongated hump covered by an extinguisher-shaped shell. In most cases the twisting, as viewed from above, has taken place in a direction opposed to the hands of a watch, but in some few snails the opposite has been the case, so that the spiral shell is left-handed.

A little observation at the sea-side will show that Periwinkles are in the habit of creeping about on the rocks, feeding on sea-weed, from which they are able to scrape small pieces by means of the rasping organ. The part of such an animal which protrudes from the shell will be seen to be bilaterally symmetrical, and to mainly consist of a foot much smaller than that of the Ormer (see p. 307), and a head provided with a prominent snout and two tentacles, each of which bears a small eye at its base in the form of a black spot. The projecting hind-end of the foot bears upon its upper side a horny plate, the *operculum*, which when the animal is completely withdrawn into the shell by means of the shell-muscle stops up the aperture, thus guarding the only weak point in the defences. The operculum corresponds in shape with the aperture or mouth of the shell, which here, as in vegetarian snails generally, possesses a continuous margin devoid of any notch.

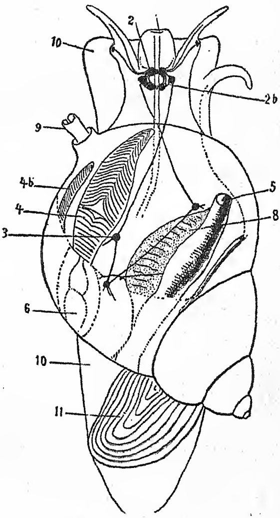


Fig. 182.—Diagram of a Comb-gilled Snail, seen from above. The roof of mantle-cavity and overlying shell supposed transparent.

1, Mouth; 2, brain-ganglion; 2*b*, nerve-cord connecting side-ganglion (above) with foot-ganglion (below); 3, one of the three ganglia on the twisted nerve-loop; 4, gill; 4*b*, osphradium; 5, opening of intestine; 6, heart in pericardium; 8, a gland (purple-gland in Purpura); 9, siphon; 10, 10, foot; 11, operculum.

Examination of the mantle-cavity and the related organs will show several important points of difference from the Ormer (see p. 308). As before, the last part of the intestine can be

seen, lying, however, well over on the right side, while on the left there is a single *gill* with the comb-like shape characteristic of the order, and running alongside it a projecting ridge, the *water-testing organ* (osphradium). The *heart* is placed immediately behind the gill, and has but one auricle, placed in front of the ventricle, which is not folded round the intestine as in the Ormer. It is indeed exceptional for the intestine of a snail to run through the heart, though it is characteristic of bivalve molluscs. There is but one *kidney* in the Periwinkle, opening into the back of the mantle-cavity, on the left-hand side. The suppression of one gill, auricle, and kidney is believed to be one result of the twisting of the body, though exactly why is uncertain. They have perhaps been subjected to pressure, and so to speak squeezed out of existence. The twisting of the visceral loop in the nervous system is another result of the coiling of the body, and this is easily understood.

Two species closely related to the Periwinkle are common on British coasts. In one (*Littorina rudis*) the coiled apex or spire of the shell is very short. The other (*L. obtusata*) is a small form, varying in colour from greenish-brown to orange-yellow, and entirely devoid of a projecting spire, the apex of the shell being rounded off so as to make the general outline of the shell spheroidal. It is common on the brown sea-weed (*Fucus*) with which 'tween-tide rocks are often thickly covered.

The River-Snail (*Paludina*), common in the streams of this country, is something like the Periwinkle in general shape, but it is a good deal larger and the shell is much thinner.

Living side by side with the Periwinkle on our rocks will be found the Purple Snail (*Purpura lapillus*), with a dense angular white shell extremely unlike the rounded covering of the former species. It belongs to a different family, and is a good example of a carnivorous sea-snail. The mouth of the shell is notched at its front end, *i.e.* the end away from the spire, for the transmission of the *siphon*, a spout-like prolongation of the mantle by means of which water enters the mantle-cavity. The Purple is one of the forms in which the pharynx with its rasping organ is situated in the end of a long *proboscis*, that is retracted when not in use. The typical genus of this particular family is *Murex*, many of the tropical species of which possess extremely beautiful shells, covered with long spines and having the front angle of

the mouth drawn out into a long canal for the reception of the siphon. Tyrian purple was obtained from species of Murex and Purpura, the organ yielding it being a gland in the roof of

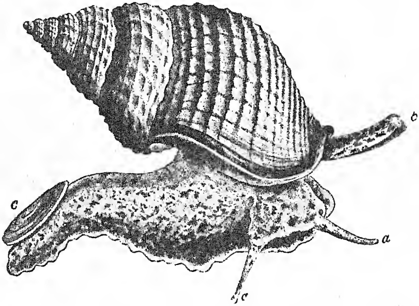


Fig. 183.—Whelk (*Buccinum*). *a a*, Tentacles; *b*, siphon; *c*, operculum

the mantle-cavity, of which the juice turns purple on exposure to sunlight.

The Common Whelk (*Buccinum undatum*) (fig. 183), inhabiting both shallow and deep water around our coasts, closely resembles the Purple in structure, but is very much larger.

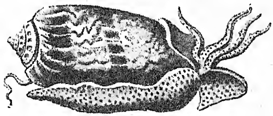


Fig. 184.—Olive (*Oliva*)

As examples of other families may be mentioned:—Mitre-Shells (*Mitra*), Volutes (*Voluta*), Olive-Shells (*Oliva*) (fig. 184), Harp-Shells (*Harpa*), Cone-Shells (*Conus*), Turret-Shells (*Turritella*), Wing-Shells (*Strombus*) (fig. 185), Helmet-Shells (*Cassis*), and Cowries (*Cypræa*) (fig. 186). In many of these the shells are extremely handsome, and occupy a prominent place in museums and private collections.

Special mention must be made of the *Heteropods*, a group of comb-gilled snails which swim freely in the open sea. The body in these pelagic forms is transparent, and the foot is a laterally-flattened fin-like structure, by means of which the animal swims back downwards. The shell may be spiral (*Atlanta*) or cap-shaped (*Carinaria*), but in some cases (*Pterotrachea*) is entirely absent.

Order (2). *Shield-gilled Snails* (Aspidobranchia).—As already mentioned, these forms possess a gill or gills in which the axis has a series of plates on either side. The primitive bilateral

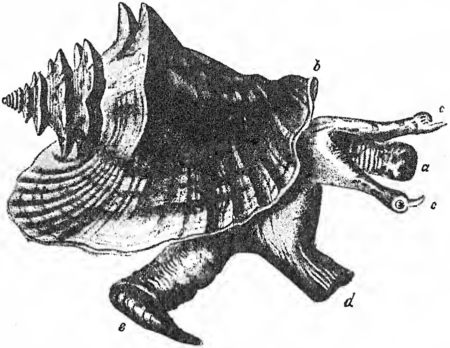


Fig. 185.—Strombus

a, Proboscis; *b*, notch in shell-mouth; *c*, eye-bearing tentacles; *d*, foot; *e*, operculum.

symmetry of the body has not been disturbed to the same extent, for both right and left gills, auricles, and kidneys may be present.

There are fifteen families, of which one, the *Trochidæ*, represented by twenty British species, may be taken as representing forms with well-coiled shell, the colours and markings of which are often of extreme beauty. Two auricles and kidneys are present, but only one gill.

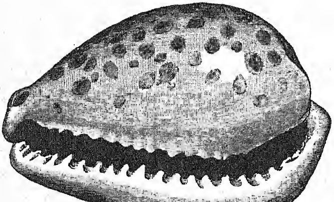


Fig. 186.—Cowry (*Cypræa*)

The Ormer (*Haliotis tuberculata*), already described (pp. 307–311), is the type of another family, and, as we have seen, it possesses two auricles, gills, and kidneys. There is good reason to believe that it is descended from forms possessing a well-coiled visceral hump, covered by a shell of corresponding shape, and large enough to serve as a retreat into which the animal could withdraw itself at the approach

of danger. Although the hump and shell still retain a certain amount of twisting they have been flattened out to a large extent, and the shell no longer serves as a refuge. This, however, is made up for by the immense size of the foot, by which the animal can adhere firmly to the rock, at the same time pulling the shell down so as to cover the exposed parts.

In the much smaller Key-hole Limpet (*Fissurella Græca*) of the Mediterranean the visceral hump is completely flattened out, and the shell is conical, with a hole at the apex communicating with the mantle-cavity. It possesses two gills, &c., like the Ormer.

In John Knox's Limpet (*Acmæa testudinalis*), not uncommon on certain parts of the British coast, still further changes have taken place, for there is only one auricle and a single gill. Nor does the intestine pass through the heart, as is the case in the shield-gilled forms so far mentioned. The Common Limpet (*Patella vulgata*) agrees with this species in most respects, but has lost both the gills, at least as functional breathing-organs. If the small mantle-cavity lying above the neck be cut open the end of the intestine will be seen projecting into it, and on each side of this the opening of a kidney. On the floor of the cavity are two little orange-coloured projections, examination of which as to structure and nerve-supply shows that each represents the vestige of a gill covered by its water-testing organ (osphradium). The Limpet, however, does possess *gills*, though of another kind, which are seen as a large number of flattened plates running right round the body well above the foot and overhung by the mantle skirt, which is a well-developed continuous flap. Since these gills are not the equivalents of the ordinary plume-like gills characteristic of Molluscs they are termed *secondary* gills. This use for the word secondary is a common one in zoology.

At first sight a Limpet, with its simple conical shell, might be taken for a very primitive animal. If it were so, however, the mantle-cavity, with its related organs, would be at the hind end of the body instead of in front, and the nerve-loop of the nervous system would not be, as it is, 8-shaped. These considerations, and comparison with other forms, would lead to the conclusion that the apparent simplicity is secondary, and that the Limpet's ancestors were forms with spirally coiled visceral hump and shell. A very interesting confirmation of this con-

clusion is afforded by the life-history, for at an early period of its existence, when it is a free-swimming larva, it actually does possess spirally twisted visceral hump and shell. This is another example of the law of recapitulation previously exemplified (see p. 14).

Sub-class 2.—EUTHYNEURA

These are forms in which the nerve-loop of the nervous system is not twisted (except in one family), but it would appear that this is not, as might at first sight be supposed, a primitive feature, but the result of an untwisting process. A further character is the possession of two pairs of tentacles by the head. There are two orders: 1. Hind-gilled Snails (Opisthobranchia), with the auricle of the heart behind the ventricle, and the gill in a corresponding situation; and 2. Lung Snails (Pulmonata), in which the gills are entirely absent and the mantle-cavity has been converted into a lung.

Order 1.—HIND-GILLED SNAILS (Opisthobranchia)

A very great variety of marine forms are placed in this order, some snail-like in appearance, others slug-like, and others again of modified shape and adapted for swimming in the open sea. A distinction is drawn between species in which there is typically a gill sheltered in the mantle-cavity (Tectibranchs), and the Sea-Slugs (Nudibranchs), devoid of mantle and shell.

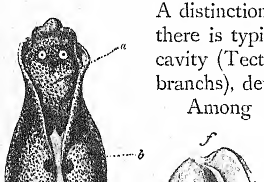


Fig. 187.—Bubble-shell (*Bulla*) *a*, Head-lappets; *b*, right epipodium; *c*, shell; *d*, mantle-lobe; *e*, hind-end of foot; *f*, shell.

Among the *Tectibranchs* the Bubble-Shells possess a thin translucent spiral shell (fig. 187), overlapped by a body-fold (epipodium) each side.

Another related family is exemplified by a small white mollusc, *Philine aperta*, very common in shallow water round the British coast. The shell is something like that of a bubble-shell, but is not visible externally, as folds of the mantle have grown completely over it. In the Sea-Hare (*Aplysia*) the shell is still further reduced, being a thin oval plate situated on the upper

side of the body and almost entirely covered over. A large *gill* is present, protected in a *mantle-cavity* which opens on the right-hand side (see fig. 188). The external opening of the single *kidney* is at the root of the gill, and the intestine terminates still further back outside the mantle-cavity altogether. The Sea-Hare was at one time pointed to as a good example of a form in which the twisting process had begun, carrying the mantle-cavity with its organs on to the right side. If this were so, however, we should expect to find two auricles to the heart, two gills, and two kidneys, which is not the case. A more adequate explanation is that the Sea-Hare is descended from forms in which coiled visceral hump and shell were present, and which had lost an auricle, a gill, and a kidney; forms, in fact, resembling such a species as the Periwinkle in structure (see p. 318). We must suppose that in these the visceral hump gradually flattened out and the shell gradually became reduced, while at the same time a certain amount of untwisting took place, bringing back the mantle-cavity to the right-hand side of the body. In this way a secondary or spurious simplicity has been acquired. The non-twisted nerve-loop (fig. 188) is characteristic of Euthyneura generally.

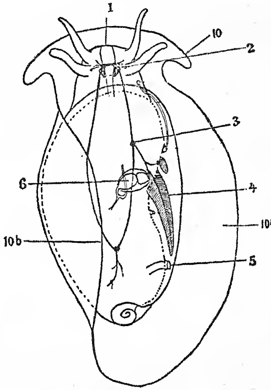


Fig. 188.—Diagram of a Tectibranch Snail, seen from above

1, Mouth; 2, nerve-ring with ganglia; 3, one of the two ganglia on the untwisted nerve-loop; 4, gill, just in front of which is seen the osphradium; 5, opening of intestine; 6, heart in pericardium; 10, 10*a*, right epipodium; 10*b*, left epipodium folded over back.

Eight out of the twenty families embraced by the Tectibranchs are collectively known as the *Wing-footed Snails* or *Pteropods* (Gk. *pteron*, a wing; *pous*, a foot), formerly regarded as a distinct class of the Mollusca. They are small pelagic creatures, vast shoals of which are to be found swimming in the open sea. Some of them possess a mantle-cavity and a transparent shell either spiral or conical in shape. In these the foot is transformed into a pair of fin-like structures. Others again have no mantle and shell, and though they possess fins,

these are not formed from the foot, but from the region of the body immediately above it, and equivalent to flaps found in this position in the Sea-Hare (epipodia) or to the halves of the funnel in a Pearly Nautilus (see p. 317).

Sea-Slugs (Nudibranchs).—These are beautifully coloured creatures with a large creeping foot. Their symmetrical form is not a primitive character, but due to the untwisting process just described for the Sea-Hare. Here, however, modification has gone a stage further, for not only is there no shell, but both mantle-cavity and the typical plume-like gill are absent. The intestine opens in the middle line on the posterior part of the body.

A common British genus is *Doris*, in which the absence of plume-gills is made up for by the presence of a circlet of branched *secondary gills* situated on the upper side of the body around the opening of the intestine. If the expanded gills of a living specimen be touched they are immediately drawn in, being sheltered in a ring-like groove when so retracted. Another common genus is *Eolis* (fig. 189), in which the back is studded with numerous slender club-like processes.

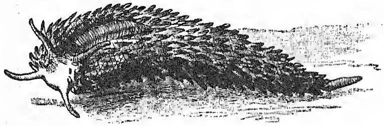


Fig. 189.—Eolis

A very interesting little Nudibranch is the free-swimming Mediterranean form *Phyllirhoë*, which possess a transparent laterally-flattened body and is devoid of foot. There are numerous little phosphorescent bodies in the skin.

Order 2.—Lung Snails (Pulmonata)

The seventeen families of this order are mostly inhabitants of the land or of fresh-water, and familiar examples are furnished by the land-snails and slugs. The common Garden Snail (*Helix aspersa*) may be taken as an illustrative type (fig. 190).

The part of the body which is protruded from the shell when the animal crawls is symmetrical, and its under part is made up of the well-developed *foot*, which has a rounded front end and ends in a point behind. The head is fairly distinct, and bears

two pairs of *tentacles*, which are hollow and can be drawn back into the body. The front pair are short, while the others are long, and each of them bears an eye at its tip. There is a well-coiled *visceral hump* covered by a *shell* of corresponding shape, into which the animal can be withdrawn, though there is no operculum to guard the entrance. During the winter the snail

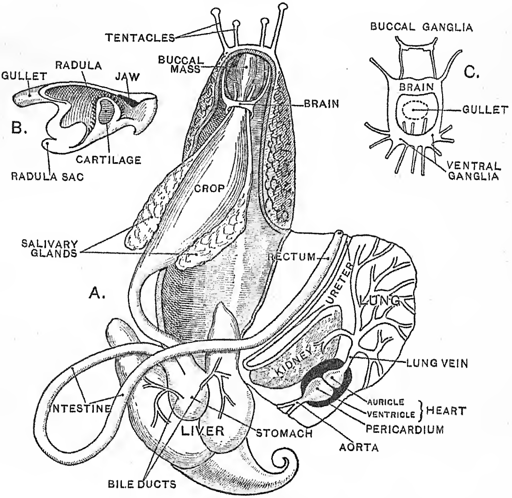


Fig. 190.—Structure of Garden Snail (*Helix aspersa*)
A, General dissection, from upper side; roof of lung spread out to right. B, Buccal mass, right half removed. C, Nerve-ring, from back.

remains in a torpid condition within its shell, or in other words *hibernates*, under which condition the want of operculum is compensated for by the formation of a limy partition across the mouth of the shell, leaving, however, a small aperture for breathing purposes.

As would be expected in a form so twisted, the *mantle-cavity* is in front, but no longer has a wide opening to the exterior, as this would lead to its delicate lining being dried up. There is, instead, a small aperture on the right-hand side, easily seen just within the margin of the shell. When the mantle-cavity is opened

no trace of a gill can be seen, but the thin *mantle* which forms its roof is raised up into a net-work of ridges traversed by blood-vessels and acting as a lung. The intestine runs down the right side of the mantle-cavity to its termination close by the lung-opening, and by its side runs the slender tube which carries off the waste matter from the single *kidney*, abutting against which is the pericardium containing a two-chambered *heart*.

The *nerve-ring* encircles the beginning of the gullet just behind the pharynx, and the nerve-loop is exceedingly short, and fused with it in such a way as to be exceedingly difficult to recognize. About 6000 species are included in the Pulmonata, and of these some 3500 belong to the same genus (*Helix*) as the Garden Snail. A much larger species than this is the Roman Snail (*Helix pomatia*), common abroad, and on the chalk downs of Kent and Surrey. It is said to have been introduced in Roman times for culinary purposes.

Land-Slugs may be regarded as derived from snail-like forms which have been more or less flattened out, and in which the shell is reduced or, it may be, absent altogether. Two common British species may be mentioned as examples, the small grey Field-Slug (*Limax agrestis*) with a reduced internal shell, and the much larger Black Slug (*Arion ater*) in which the shell is entirely absent.

The Pulmonate forms so far mentioned all agree in the possession of four tentacles, with eyes situated on the tips of the larger posterior ones. But there are still other forms in which only one pair of tentacles is present, at the bases of which the eyes are placed. Among these may be mentioned the Pond-Snail (*Limnæa stagnalis*) with a thin, pointed shell, and the Trumpet-Shell (*Planorbis corneus*), also an inhabitant of fresh water, and possessing a flat spiral shell.

CLASS 3.—BIVALVE MOLLUSCS (LAMELLIBRANCHIA)

The shell of a Gastropod, when it possesses one, always consists of one piece or valve, *i.e.* is *univalve*; but in the class now to be considered there is a *bivalve* shell consisting of a right and a left valve. The *Fresh-water Mussels*, abundant in many of our streams, canals, and ponds, furnish a convenient type. They belong to two genera, *Anodon* and *Unio*, which agree in

their main features, though there are certain differences, especially as regards the shell.

External Characters.—The animal is completely invested by the two elongated oval pieces which make up the shell, and are right and left respectively (fig. 191). They are united together above, along what is called the *hinge-line*, and can either be brought close together elsewhere so as entirely to cover the soft parts, or may be separated so as to "gape" more or less, which is always the case in dead specimens. A series of closely-set lines following the curve of the shell can be seen on the outside, and it will be found that these "lines of growth", which mark successive additions of material, have as their centre a pointed projection near the straight upper edge of the valve, known as the *beak* or *umbo.* This clearly marks the oldest part, and, as in bivalves, usually projects forwards, and is nearer the front than the back end. When the shell is removed from the soft parts by cutting through certain muscles, it will be found that each valve covers a soft flap which lines it during life, and is really half the *mantle* (fig. 192), here clearly divided into right and left halves, which may be compared to the flaps of a man's coat, if the further assumption be made that the coat is a part of the body and its flaps are big enough to entirely cover the occupant.

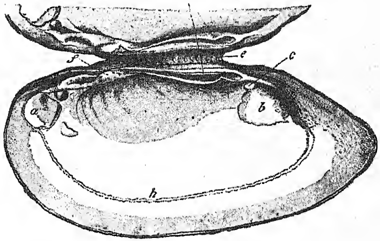


Fig. 191.—Shells of Fresh-water Mussel (*Unio*), seen from within *a b*, Impressions of anterior and posterior adductors; *d f*, hinge-teeth; *e*, ligament; *h*, pallial line.

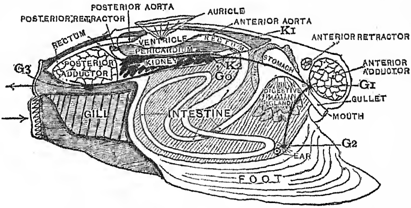


Fig. 192.—Structure of Fresh-water Mussel (*Anodonta*) G1–G3, ganglia: Go, opening of oviduct; K1 and K2, internal and external kidney-openings

Structure and Formation of the Shell.—The shell is a horny structure largely impregnated by salts of lime. It is produced by the underlying epidermis, from which a sticky substance exudes which afterwards becomes hard. In all classes of Molluscs the mantle has a great deal to do with the formation of the shell, but even here, where the mantle is very well developed, it does not line the part of the shell near the hinge-line, and yet that part can be repaired if broken. In a Garden Snail the mantle is of comparatively small extent, the chief part of it being the roof of the lung, yet all parts of the snail's shell can be repaired. The shell of the Mussel, and the same thing is true for a land- or sea-snail, consists of three layers: (1) a greenish external skin, often called incorrectly the epidermis; (2) a middle prismatic layer in which the calcareous material consists of oblique prisms; and (3) an internal pearly layer, made up of numerous thin lamellæ, the edges of which form a series of minute wavy ridges on the inner side of the shell, which are the agents to which the rainbow tints of the pearly layer are due. The edge of the mantle is thickened, and, both here and in most Mollusca, plays a very important part in the formation of the shell, the two outer layers originating from it alone. Repairs, therefore, except at the edge of the shell, are carried out in pearly material only, though further observations are wanted on the subject.

The two valves are united together in the region behind the umbo by a horny elastic band known as the *ligament*, which is kept on the stretch when the shell is closed. In the shell of Unio (fig. 191) there are projecting *teeth* along the inner side of the hinge-line in each valve, which fit into corresponding sockets in the other valve. Such teeth and sockets are entirely absent in Anodon, whence its name (Gk. *an*, without; *odous*, a tooth). The inner side presents a number of markings due to the attachment of muscles, and therefore called *muscular impressions*. The two largest of these are oval, and situated respectively near the front and back ends. They correspond (see fig. 192) to a couple of large muscles, the fibres of which run transversely across from valve to valve, and which, since their contraction serves to adduct or pull the valves together, are termed the anterior and posterior *adductor muscles* (L. *adduco*, I lead to). When they cease to contract, the elasticity of the stretched ligament comes into play

and pulls the shell open. Running from one adductor scar to the other is a curved *pallial line*, marking the attachment of the pallium or mantle to the shell. In a case like this, where the line is unbroken by any indentation, it is *integropalliate*, a point which will be referred to later when other bivalves are considered.

Both shell and contained animal are bilaterally symmetrical, a fact which is expressed as regarding the former by using the term equivalve. Each valve is in fact a mirror-image of the other, but in itself does not exhibit bilateral symmetry, *i.e.* is *inequilateral.*

The Mussel is in the habit of remaining obliquely buried in the mud with its hinder end projecting, and examination of an aquarium specimen in this position will show two openings, one above the other, between the mantle lobes (fig. 192). Water-currents continually set into the lower or *inhalent aperture*, serving the double purpose of carrying food to the mouth and oxygen to the breathing-organs, while other currents as constantly flow out of the upper or *exhalent aperture*, taking with them the various forms of waste matter. The inhalent aperture is fringed with sensitive tentacles, and if these are touched the shell at once closes, an arrangement which is obviously protective. The Mussel, therefore, is able to feed, breathe, and get rid of waste, with most of its body concealed from observation.

After removal of the shell (fig. 192) it will be found that the mantle-lobes are not united together except between the two apertures just described. If one of them be turned back other parts come into view, and the first thing to determine is which is front and which back end. A distinct head will be looked for in vain, and its absence is one of the characters of this class, which sometimes receive the name of "headless" Molluscs (*Acephala*, from Gk. *a*, without; *kephalon*, a head). This cannot be regarded as a primitive feature, and there is good reason to believe that the bivalves are descended from forms which possessed a distinct head, the dwindling of which has been brought about by a sluggish mode of life and dependence as regards food upon minute organisms brought to the mouth by water currents. The *mouth* will be seen in the Mussel as a wide slit just behind one of the adductor muscles, at the end further from the inhalent and exhalent apertures, which thus mark the hinder end of the animal. There is a complete absence of anything in the way of jaws, but a pair of soft leaf-shaped bodies,

the *labial palps*, may be seen on either side of the mouth. The body hangs down between the mantle-lobes, and its ventral part is modified into the orange-coloured *foot*, which, instead of presenting a creeping under surface, as in a snail, is flattened from side to side and projects forwards as a muscular body which has been variously compared, as regards its shape, to an axe or ploughshare. It can be protruded from between the valves of the shell, and serves as a pushing-organ, by which the animal can slowly plough its way through the mud with its front end first.

Very conspicuous are the plate-like *gills*, which have suggested the scientific name of the class (Lat. *lamella*, a plate; Gk. *branchia*, gills), and which are not only breathing-organs but are also largely concerned with setting up the currents of water which play such an important part in the life of the animal, being largely aided, however, in both these duties by the lobes of the mantle. The water-currents are a result of ciliary action (see p. 49). Each gill consists of an outer and an inner plate, and, despite its specialized form, has been produced by the modification of a gill-plume similar in kind to those found in the Ormer (see p. 308). The stem of the gill runs fairly parallel to the long axis of the body, and is attached to the body-wall above. The *mantle-cavity* is here the huge space between the mantle-lobes into which the gills and lower part of the body hang down, and, by the attachment of the former to adjacent parts, it is divided into a large lower section into which the inhalent aperture leads and a much narrower upper portion, above the gills, and communicating with the exterior by the exhalent aperture. This is most clearly seen behind the posterior adductor muscle, where the inner plate of one gill is seen to be fused along the middle line with the corresponding plate of the other gill, thus forming a partition between the upper and lower sections of the mantle-cavity.

Digestive Organs (fig. 192).—The most striking feature is a negative one, consisting in the entire absence of the characteristic rasping organ (odontophore) possessed by the other molluscan classes. It is believed that bivalves are descended from ancestors which were provided with this structure, which has been lost as a result of the same conditions which led to the dwindling of the head, and which have already been alluded to. The mouth leads into a short gullet, which opens into a stomach, that again continues into a coiled intestine, the last part of which runs up

to the dorsal side, traverses the heart (see below), and runs back over the posterior adductor to its termination in the upper section of the mantle-cavity.

Circulatory Organs (fig. 192).—The *heart*, situated in a pericardial cavity, has the dorsal situation characteristic of Invertebrates, and is essentially similar to the heart of the Ormer (see p. 308), consisting as it does of a central ventricle to which a thin-walled auricle is attached on either side. Purified blood is received by the auricles from the mantle-lobes and gills, and then passes into the ventricle, which distributes it to the body.

Respiratory and Excretory Organs (fig. 192).—As already mentioned, the function of breathing is carried out by mantle-lobes and gills. As to excretion of nitrogenous waste, this is effected by two elongated brown *kidneys* underlying the pericardium, with which they communicate on the one hand, while they open to the exterior on the other.

Nervous System and Sense Organs (fig. 192).—The *central nervous system* consists, as in the Ormer (see p. 310), of a nerve-ring and a nerve-loop. The former presents a ganglion on each side of the mouth (equivalent to one of the brain ganglia of the Ormer with a lateral ganglion fused with it) connected with one another above and with a pair of foot-ganglia embedded in the body close to the muscular foot. The nerve-loop is connected in front with the upper ganglia of the ring, and its posterior end lies just below the posterior adductor, where it is thickened into a pair of visceral ganglia. The three pairs of ganglia send out nerves to the parts of the body in their neighbourhood.

The Mussel undoubtedly possesses the sense of *touch*, especially as regards the edge of the mantle. It is also probable, though not absolutely certain, that it is endowed with *smell* and *taste*, and *water-testing organs* (osphradia) can be recognized near the visceral ganglia, though there is some doubt about their function, for they lie in the upper section of the mantle-cavity in the course of the outgoing currents of water, which is not in accordance with their supposed function. So-called *organs of hearing* are present, as in the Ormer (see p. 310), in the form of two little vesicles connected with the foot-ganglia and containing particles of carbonate of lime. They are probably concerned with the sense of equilibrium. Eyes are altogether absent.

Lamellibranchs are divided into five orders based on the

characters of the gills, and embrace between them some forty families. It will be enough for our present purpose to mention a few common species in illustration of the range of characters found within the class.

The *Cockle Family* includes a large number of shallow-water forms found along coasts and estuaries in most parts of the world. They are especially characteristic of places where sand is abundant. The best-known British form is the Edible Cockle (*Cardium edule*) of the Atlantic and Mediterranean areas. The shell is rounded in outline, and marked by prominent ribs which radiate from the beak. The edges of the mantle-lobes are much more extensively united than is the case with the Fresh-water Mussel, but an orifice is left in front through which the foot can be protruded, and at the back inhalent and exhalent apertures are seen as before, a striking difference being that they are here placed at the ends of two short tubes or *siphons*, both fringed by tentacles. The narrow bent *foot* is able not only to push the animal through the sand, but also by its sudden contraction to bring about springing movements in the water. The siphons can be drawn back within the shell by means of a special *retractor muscle*, and the attachment of this to the shell causes the pallial line to be indented at its posterior end, just as, to use a somewhat fanciful comparison that has been employed, a coast-line is broken by a bay or, to use the Latin word, *sinus*. By examination of the shell only we are therefore able to say in a given case (fig. 193) whether siphons of any size were present, the extent of the bay being roughly proportional to their development. This *sinupalliate* condition is contrasted with the integro-palliate one described for the Mussel (p. 331), but it must not be forgotten that small siphons may be present devoid of muscles sufficiently powerful to indent the pallial line perceptibly.

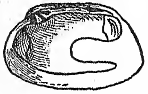


Fig. 193.—Inside of right valve of a sinupalliate shell. The bay (sinus) in the pallial line is seen on the right

The *Gaper Family* presents a certain amount of resemblance to the preceding as regards habit, and a common British form, the Sand Gaper (*Mya arenaria*) (fig. 194), is found both in mud and sand off many parts of our coast, and also on the opposite side of the North Atlantic. The thick oval shell is not ribbed like the Cockle, and the name "Gaper" has reference to the

fact that the valves cannot be brought together behind owing to the presence of enormous *siphons* that can only be drawn back into the shell to a limited extent. The two siphons are united into a single fleshy mass with two orifices at its tip, and protected by a brown wrinkled layer continuous with the outer horny layer of the shell.

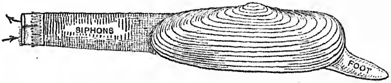


Fig. 194.—Sand-Gaper (*Mya arenaria*)

The protective arrangement suggested in the Mussel (see p. 331) is here carried to a much greater extent, for when the animal is buried in the mud, with only the tip of the siphon-tube projecting, it is singularly inconspicuous, though feeding and breathing can go on without interruption. The foot of the Gaper is small, and is of no use for springing.

Fig. 195.—Razor-Shell (*Solen*). Foot seen on left, siphons on right

A closely-related family is that of the *Razor-shells* (fig. 195), of which two British species are very common, *i.e. Solen siliqua* and *Solen ensis*. In both cases the shell is very long and narrow, and gapes at both ends, but in the former species it is straight and in the latter curved.

Some very interesting boring molluscs come fairly close in affinity to the Gapers. The *Rock-borers* (*Saxicava*) and *Piddocks* (*Pholas*) (fig. 196), both of which can excavate burrows in hard rock, include a number of British species belonging to two families, while a third family is represented in the Atlantic and Mediterranean by the so-called "Ship-worm" (*Teredo navalis*) that often completely riddles timber with its burrows, which are lined by a smooth shelly layer secreted by the surface of the long siphonal tubes.

All the preceding families belong to one, and that the largest, of the five orders of bivalves. We may take the *Sea Mussel Family* as representing another order, and of the forms included by far the most familiar, largely on account of its economic importance, is the Edible Mussel (*Mytilus edulis*) (fig. 197), of which vast numbers are found together attached to stones, wooden piles, or other firm objects, by means of strong blackish threads constituting the *byssus*. The dark bluish shell is somewhat wedge-

shaped, and the sharp beaks are placed at the extreme front end. There are no siphons, but merely two apertures, as in the Fresh-water Mussel, the inhalent one being very large and fringed. The small dark *foot*, though capable of being used as a locomotor organ, is not in constant employment as in free bivalves, which probably accounts for its relatively small size. The byssus arises from a deep pit behind the foot, and though it is commonly found

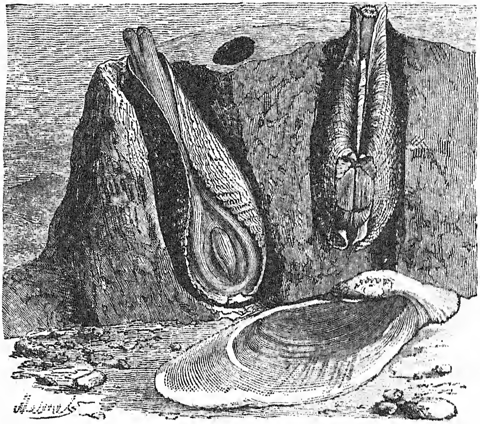


Fig. 196.—Piddocks (*Pholas dactylus*) in their Burrows

mooring the animal, it can be cast off if necessary, enabling the animal to creep away to some more desirable spot. The anterior adductor muscle is much smaller than the other, and this point is of special interest, because it foreshadows cases where only the posterior adductor is present in the adult. This is a tendency to specialization, but the gills on the other hand are simpler in structure than those of a Fresh-water Mussel, for though they consist of two plates on each side, yet each of these can easily be broken up into distinct filaments. The gill is, in fact, a somewhat modified plume-gill in which the separate side-branches of the plume have not yet firmly united into plates, as in the fresh-water mussel.

The *Ark-Shells* constitute a family belonging to the same

order as the Marine Mussels, and agree with them in the character of the gills. The shell is somewhat rectangular in form, with a long hinge-line possessing many small similar teeth. The foot has a flattened under-surface, an exception to the general rule among bivalves. The group is represented by species in all parts of the world, and some of the individual species have a very wide distribution, as in the case of the British species *Arca lactea*.

In the *Scallop Family* we have represented a third order of bivalves which possess gills more complicated than those of Ark-Shells and Edible Mussels, but less so than in the Fresh-water Mussel and associated families. There are several species of British Scallops belonging to the genus *Pecten*, in which the shells are fan-shaped. The Pilgrim Scallop (*Pecten Jacobæus*) (fig. 198) is interesting as the source of the "cockle-shell" which the mediæval pilgrim to the Holy Land wore in his hat. Only one adductor muscle is present, the equivalent of the posterior one in the families so far mentioned. In some of the species the valves of the shell are equal according to the general rule, and in these the animal is able to swim by flapping them. In other cases, of which the edible Scallop commonly seen in fishmongers' shops furnishes an example, the animal is sedentary, and during life rests with its right valve below, this being well curved, while the upper or left valve forms a flat lid. A byssus is present,

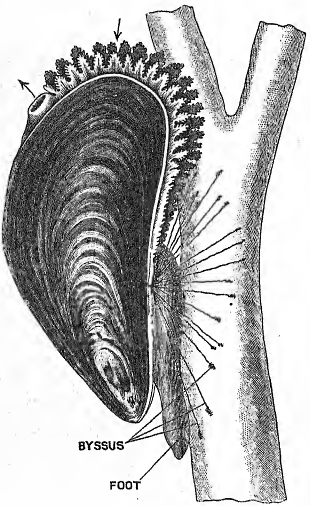


Fig. 197.—Edible Mussel (*Mytilus edulis*)

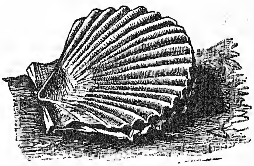


Fig. 198.—Pilgrim Scallop (*Pecten Jacobæus*)

serving to attach the creature to some firm object. There is in this genus an interesting variation on the mode of opening the shell described for the Fresh-water Mussel (see p. 330). There is no external ligament but what is called an *internal ligament* or cartilage, placed in a deep pit at the hinge and kept compressed when the shell is shut. When therefore the adductor muscle ceases to contract, the elasticity of this body will come into play, causing the shell to gape, just as a door might be made to fly open by the expansion of a piece of india-rubber shut into its hinge and thereby strongly compressed. The mantle-lobes of Pecten are quite free from one another, so that not only are siphons absent but also special inhalent and exhalent openings. The long plate-like *gills* follow the curve of the body, and water has ready access to them through the wide cleft between the mantle-lobes exposed when the animal opens its shell. The edge of the mantle is fringed by long tentacles, and bears quite a number of spherical eyes of a beautiful green colour. These have a very complicated structure, approaching in some respects to the eyes of Vertebrates.

The *Oyster Family* is closely allied to the preceding, but its members are still more modified. The shell is very irregular, and the animal is attached by the substance of the left valve, which in the Common Oyster (*Ostrea edulis*) of British seas is hollowed out while the right valve is lid-like, just the opposite to what is the case in a Scallop. The foot is entirely absent, and though the mantle-edges bear short tentacles, they are devoid of eyes.

Brief mention may be made of the *Nucula Family* as representing a comparatively small order of bivalves in which the gills present primitive characters. In the type genus *Nucula*, for example, the gill on each side is small and obviously like one of the gill-plumes of the Ormer, and a further primitive character is found in the possession of a foot with flattened creeping surface.

CLASS 4.—TUSK-SHELLS (SCAPHOPODA)

This small class includes the typical genus Dentalium and its allies. A British form, the Common Tusk-Shell (*Dentalium vulgare*) (fig. 199), may be taken as a type. It is found burrowing in the sandy parts of the sea-floor. The curved body is bilaterally

symmetrical, with the upper side concave, and it is covered by a tubular *shell* shaped something like an elephant's tusk, whence its name. This shell has an aperture at each end, the larger one being in front, and its formation may be understood if we suppose the presence of two long mantle-flaps which have fused together in the middle line below, and that shelly matter has been secreted continuously all round. This view is justified by the development. So far there would appear to be affinity with the bivalve molluscs, and this is confirmed by the shape of the *foot*—which, however, has a lobe each side as well as a central portion—and by the character of the *nervous system*. In other respects there is an approach to Gastropods, for though the head is much reduced it is not entirely absent, the mouth being placed on the end of a short non-retractile *proboscis*, behind which is a pharynx provided with the typical *rasping-organ*.

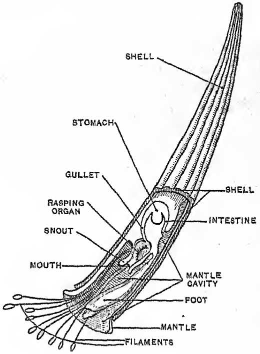


Fig. 199.—Tusk-shell (*Dentalium*). Shell partly removed

Springing from the base of the proboscis are two bunches of long filaments dilated at their ends, and capable of protrusion for some distance from the mouth of the shell. These are supposed to be of use in capturing small organisms as food, and it is possible that they represent the gills of other forms, though this is by no means certain.

Class 5.—PROTO-MOLLUSCS (Amphineura)

The different classes of Molluscs are all supposed to have sprung from bilaterally symmetrical forms with fairly distinct head, a rasping-organ, and a creeping foot. There was probably a continuous mantle-flap sheltering in the hinder-part of the body a pair of plume-like gills, near which would open the paired kidneys, one on each side of the intestinal aperture. The heart would be dorsal and posterior in position, and would most likely consist of a muscular ventricle with a thin-walled auricle on each

side. From creatures of this kind we can imagine Cephalopods, Gastropods, Lamellibranchs, and Scaphopods derived by specialization along different lines, the nature of which has been already indicated in the description of these classes. The small number of forms which make up the present class have probably retained to a higher degree than any other living forms the characters

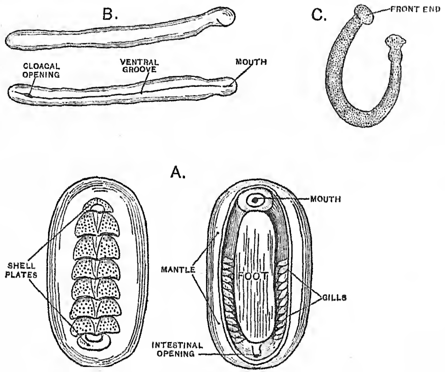


Fig. 200.—Proto-molluscs

A, Mail-Shell (*Chiton*), seen from above and below.
B, Proneomenia, right side and under surface. C, Chætoderma.

of these hypothetical ancestors, though they also have undergone modifications of their own, and it is often a difficult problem to determine which of their characteristics are primitive and which not.

The most abundant and familiar of these animals are the *Mail-Shells* or *Chitons* (fig. 200), most of which live under stones near low-water mark. A common British form is *Chiton marginatus*. In the bilateral symmetry, the presence of a fairly well-marked *head*, a broad, creeping *foot*, and a continuous *mantle-flap*, the Chitons are probably primitive. The same thing may be said regarding the dorsal *heart*, which is placed posteriorly and possesses the three typical chambers, and the *kidneys*, which are paired and open far back. The *rasping-organ*, however, is highly complex, and the *gills* are arranged in a row on each side, instead of being two in number. Quite possibly, however, the many-

gilled is more primitive than the two-gilled condition, and there are some Chitons which have a limited number of gills far back on each side. As to the *shell*, we find eight overlapping plates situated on the dorsal side.

The remaining Proto-molluscs (fig. 200) are unfamiliar marine forms inhabiting moderately or very deep water. They possess no *shell*, but the skin is beset with calcareous spicules, and they are more or less worm-like in appearance. The *foot* is either a narrow ridge placed in a longitudinal groove (*Neomenia*, *Proneomenia*), or may be entirely absent (*Chætoderma*). There is a small posterior *mantle-cavity* into which the intestine and paired kidneys open, while it may shelter a pair of plume-like *gills* (*Chætoderma*), or these may be represented by a tuft of filaments (*Neomenia*) or merely by folds (*Proneomenia*). Though at first sight the view is tempting that these genera are more primitive than Chiton, and give an indication of how Molluscs might arise from worm-like forms, it is more probable that they are simplified animals which have lost some of the typical molluscan characters, and are, so to speak, going downhill rather than uphill.

CHAPTER VIII

STRUCTURE AND CLASSIFICATION OF JOINTED-LIMBED ANIMALS (ARTHROPODA)

This is by far the largest of the great groups of the animal kingdom, including, as it does, Insects; Scorpions, Spiders, and Mites; Centipedes and Millipedes; Lobsters, Crabs, Shrimps, and a host of other Crustacea.

The Lobster, a typical member of the phylum, has already been briefly described in illustration of the characters of the higher Invertebrates (see pp. 302–304). It may be convenient to point out the respects in which it is typical of the group Arthropoda. These are: *bilateral symmetry*, the division of the body into a series of *segments* grouped into regions and bearing a series of paired *jointed limbs*, and the presence of a central nervous system consisting of a *nerve-ring* and a *ventral cord*. It may also be noted that the so-called *body-cavity* consists of a set of blood-containing spaces situated between the internal organs and the wall of the body. They form, therefore, a part of the blood-system, while the body-cavity of a Vertebrate (see p. 42) belongs to the lymph-system. Molluscs agree with Arthropods in this respect, except that in them the pericardial cavity does not contain blood, but is comparable to the corresponding cavity in a Vertebrate so far as that particular feature is concerned. In Arthropods, however, the heart is situated in a blood-containing space from which blood passes into it.

The phylum is divided into the following classes, which will be considered in the same order:—

A.—Air-breathing Forms (Tracheata).

Class 1. Insects (INSECTA).
Class 2. Spider-like Animals (ARACHNIDA).—Scorpions, Spiders, Mites
Class 3. Centipedes and Millipedes (MYRIAPODA).
Class 4. Peripatus (PROTOTRACHEATA).

B.—Aquatic Forms (Branchiata).

Class 5. Crustaceans (CRUSTACEA).—Lobsters, Crabs, Shrimps, &c.
Class 6. King-Crabs (XIPHOSURA).
Class 7. Sea-Spiders (PYCNOGONIDA).

A.—AIR-BREATHING ARTHROPODS (TRACHEATA)

CLASS I.—INSECTS (INSECTA)

This class embraces an astonishing number of species, more numerous, in fact, than those of all other groups of land animals put together. Yet, in spite of this, they do not exhibit so wide a range of characters as might be expected, so that the study of a carefully-chosen type forms an intelligible key to the entire class. The too-familiar Cockroach or Black "Beetle" (*Periplaneta orientalis*) furnishes just such a type, though the American species (*P. Americana*) obtainable in many seaports, is decidedly better on account of its larger size.

External Characters (fig. 201).—The body is obviously divided into three regions—head, thorax, and abdomen—the distinction between the first two being emphasized by the presence of a narrow neck. In such an insect as a wasp the demarcation between thorax and abdomen is equally sharp, while in many insects, on the other hand, the three regions are bounded by a continuous curved outline unbroken by constrictions.

Each one of these three regions of the body is made up of rings or *segments*, which differ very much among themselves in character, and in some places are so closely fused together that their exact number cannot be definitely made out. Arthropods, in fact, or any large group of them, furnish innumerable instances of the phenomena described elsewhere (see p. 195) in reference to the skeleton of the limbs, where all sorts of modification of a common plan may arise by unequal development of parts, fusion, and reduction. One of the lower Arthropods, for example, such as a Centipede or Peripatus, consists of a large number of similar segments which have only undergone great specialization at the head end, while in such highly specialized forms as Insects the segments have been much reduced in number, and are grouped into regions which, in correspondence with special uses, have acquired special characters.

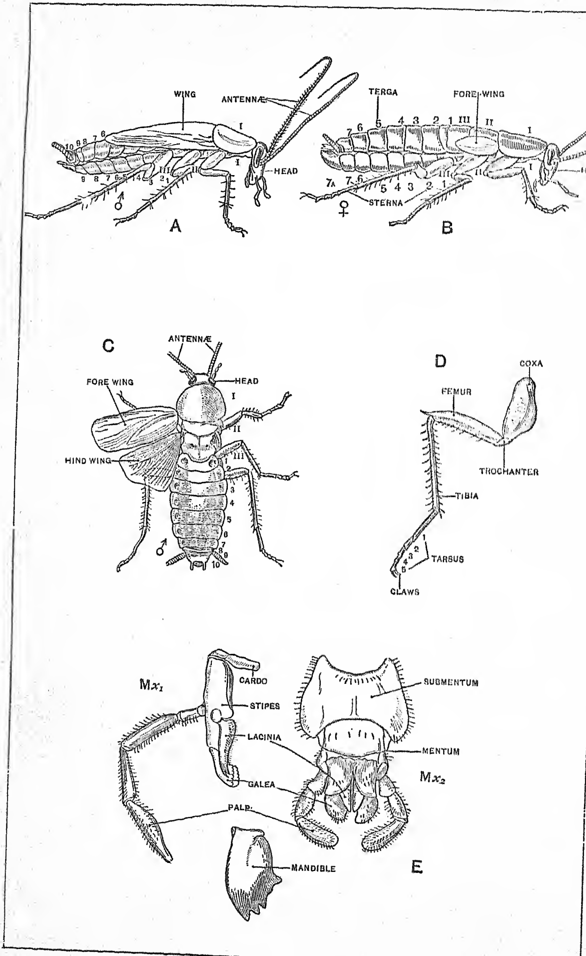


Fig. 201.—External Characters of Cockroach (*Periplaneta orientalis*)

A, B, C, Side views of male and female, and top view of male; I, II, III, segments of thorax; 1–10, segments of abdomen. D, A leg (enlarged). E, Jaws (much enlarged). Mx_1, First maxilla; Mx_2, second maxilla.

Among Insects the Cockroach is a fairly central type, and the least modified part of it is the *abdomen*, in which ten segments can clearly be distinguished. A pair of flattened jointed rods, the *cerci*, spring from the last segment, and are probably to be regarded as limbs, which are otherwise absent in this region, if certain doubtful structures be excepted. This practically limbless condition of the abdomen is characteristic of insects, and has been brought about by reduction. The *thorax* is commonly regarded as made up of three segments, and each of these bears a pair of jointed limbs or appendages in the shape of *walking-legs*. Each leg is composed of several pieces (10) movably jointed together, a character which is common to all Arthropod limbs, and has given the name to the phylum (Gk. *arthros*, jointed; *pous*, a foot). The parts of the leg differ much among themselves in respect of size and shape. The thorax also bears a pair of flattened expansions, forming the wings, attached to its second and third segments, which in the male of the common Cockroach, and both sexes in the American species, extend far backwards and overlap the abdomen. The fore-wings are horny structures, and may be termed the *wing-covers*, since they cover and protect the delicate membranous hind-wings, or wings proper. In the female of the ordinary Cockroach the fore-wings are very small and the hind-wings absent, reduction having taken place in both cases.

The *head* consists of a number of segments which have fused so intimately together that the boundaries between them cannot be made out. As, however, in the higher Arthropods the presence of pairs of jointed limbs is taken to indicate the existence of a corresponding number of segments, a certain clue is afforded, though, as all segments do not bear limbs, such evidence is only partial. In this case, as in Insects generally, there are four pairs of appendages, so that the head possesses at least four segments. The first of these are two slender jointed feelers or *antennæ*, serving as organs of touch, and probably also having to do with other senses. The remaining appendages are three pairs of jaws, named, from before backwards, mandibles, first maxillæ, and second maxillæ. As in all Invertebrates they are quite outside the opening of the mouth, and those of them which are used for biting work from side to side. Each *mandible* consists of a single broad horny piece, toothed on its inner edge,

where it bites against its fellow. The *first maxilla* on either side has a two-jointed stalk, upon the end of which are borne a slender outer and a shorter inner branch. The former is made up of a number of narrow joints, and is known as a *palp*, while the inner branch consists of two parts, a cutting blade next the middle line and a soft piece adjacent to the palp. The smaller *second maxillæ* are built on the same lines, but are fused together to form what is commonly called the "under lip" or *labium*. It is the united stalks which have so fused, and though these particular appendages are considered as jaws, the union has of course taken away any power of biting against each other. Projecting from the front of the mouth is a broad horny plate, the "upper lip" or *labrum*, and in the narrow space between this and the labium the mandibles and cutting parts of the first maxillæ work against one another. The Cockroach is clearly an example of Insects with biting mouth-parts, but in other cases we find the corresponding appendages adapted to very different uses, furnishing one of the best examples known of modifications of a common type.

A large kidney-shaped *eye* will be seen on each side of the head, and a good lens will show that each of these possesses a large number of six-sided facets. An eye like this is generally known as a "compound eye", each of the facets having been formerly regarded as equivalent to an independent simple eye. Some of the other external characters are mentioned elsewhere.

Skin and Exoskeleton.—The body is invested in a strong horny covering secreted by the underlying epidermis. Movement is rendered possible by the presence of softer areas between the firmer tracts, so that the head is not immovably fixed, the segments of the abdomen can move one upon the other, and the joints of the limbs can be bent in various directions. In fact the same problem has had to be solved as that involved in the construction of a suit of armour, *i.e.* the combination of efficient protecting power without undue sacrifice of flexibility. It is of especial importance to notice that the narrow side of the body is for the most part provided with a softer investment than the broad upper and lower surfaces.

Digestive Organs (fig. 202).—The head of the Cockroach is bent downwards at right angles to the long axis of the body, so that the mouth-opening at its end faces downwards. It leads

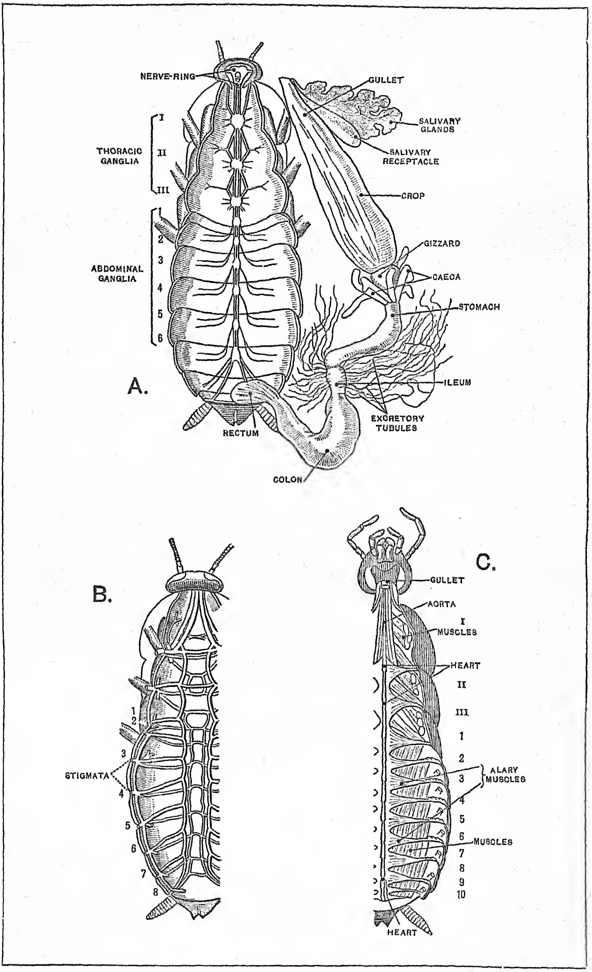


Fig. 202.—Structure of Cockroach (*Periplaneta orientalis*) (enlarged)

A, Digestive organs and nervous system. B, Air-tubes (tracheæ). C, Heart and muscles. I–III, Segments of thorax; 1–10, segments of abdomen.

into a small *mouth-cavity*, from the back of which projects a pointed *tongue*, and which passes into a narrow *gullet* continuous with a large thin-walled *crop*, and that again with a smaller thick-walled *gizzard*, from which a fairly long *intestine* runs to its termination between the cerci. The gizzard is provided with an internal chewing arrangement, such as is not uncommon among Arthropods. It consists of a firm lining raised into horny teeth and bristly ridges. Digestive fluids are poured into the digestive tube by a pair of branching *salivary glands* which open into the mouth-cavity, and a number of club-shaped "*liver*" *tubes* (digestive cæca) which encircle the beginning of the intestine.

Circulatory Organs (fig. 202).—This is not very highly specialized, for a reason to be mentioned later. The whole of the body is traversed by irregular blood-spaces of various sizes, but the only definite tubular structure is the *heart*, a long narrow blood-vessel running through the thorax and abdomen close to the upper surface. Along its sides are numerous pairs of valvular openings, through which blood passes in from the surrounding blood-space (pericardial sinus) to be pumped forwards. The heart is systemic, as it contains pure blood.

Respiratory Organs (fig. 202).—These organs present a very interesting and remarkable arrangement, for instead of the impure blood being sent to a localized lung for purification, air is conveyed to all parts of the body by means of branching *tracheal tubes*. These communicate with the exterior by means of ten pairs of small openings or *stigmata* on the sides of the body, all but the first two pairs being in the abdomen. Observation of a living Cockroach will show that the abdomen alternately dilates and contracts, the result being that air is drawn into and expelled from the stigmata. It is therefore possible to choke an insect by smearing the sides of the body with oil or some other substance which will block up these openings. The tracheal tubes appear silvery under the microscope, owing to the air which they contain, and they are lined by an elastic membrane thickened into a continuous spiral thread, so as to render them very flexible and non-collapsible. Just within each spiracle is a kind of valve, formed as a projection of the lining membrane and helping to prevent the intrusion of foreign particles.

As a result of this very thorough system of aeration, the blood

never has the opportunity of remaining impure, a fact which accounts to some extent for the imperfect condition of the circulatory organs. The restless activity of insects, and their great muscular powers, are also no doubt related to the unusually perfect state of the breathing apparatus.

Excretory Organs.—These also are very unlike anything so far described in the animal groups reviewed. They consist of a large number of very slender *Malpighian tubes*, which open into the intestine not far from its commencement.

Nervous System and Sense Organs (fig. 202).—The *nervous system* consists of a narrow and much-thickened *nerve-ring* closely encircling the gullet, and of a ventral double *nerve-cord*. The upper part of the ring is formed by a pair of large brain-ganglia, sending nerves to the eyes and antennæ, while its lower part is made up of another pair of ganglia, supplying the upper lip and three pairs of jaws. The ventral cord dilates within the thorax into three pairs of ganglia which innervate the three thoracic segments, and within the abdomen into six smaller pairs of ganglia, of which the first five belong to the corresponding abdominal segments, while the last and largest pair provide for the nerve-supply of the last five segments. Segmentation of the body as exhibited by Vertebrates, Arthropods, and some other phyla of the animal kingdom, means the existence of a number of successive rings or segments, containing sections of the various internal organs. Where the segmentation is very well marked, many structures are affected by it, and the more primitive the animal the more closely do the segments resemble one another. As regards the nervous system of Arthropods, there can be no doubt that the simplest condition is found in the presence of a distinct pair of ganglia for each segment, but Insects especially present considerable modifications of this primitive arrangement. Where a segment is relatively large, its ganglia will be so too, as seen in the thorax of the Cockroach, while fusion of segments will be accompanied by fusion of ganglia, as in the case of the jaw-bearing segments. The ganglia, further, may be among the first parts to fuse together, as seen in the last pair of the abdominal chain in the Cockroach, which represent the ganglia for the last five segments all united together, though the segments themselves are still more or less distinct.

The chief *sense organs* are those of *touch*—including the

antennæ, maxillary palps, labial palps, and cerci—and those of *vision*, as represented by the large compound eyes. There is good reason to believe that the antennæ are organs of *smell* as well as of touch, and it is probable that some of the mouth parts, perhaps the second maxillæ, have to do with *taste*. It may be further remarked that great difficulty attaches to the interpretation of many of the sense organs possessed by animals (see p. 264), and Insects, among others, are undoubtedly endowed with special senses of which it is difficult, if not impossible, for us to form any idea, our only definite standards being our own sense organs, which are those of much specialized land animals. In a subsequent chapter this interesting subject will be more fully discussed.

Life-history.—An insect such as a Butterfly or Moth goes through widely different stages in its life-history. Hatching from the egg as a caterpillar, it grows to a considerable size, and then becomes a motionless chrysalis, from which the adult insect later on escapes, its body having been formed by a series of revolutionary changes from the substance of the chrysalis body. This life-history, familiar to all who have kept silkworms, and furnishing a useful metaphor to moralists of all centuries, is one which exhibits complete change of form, or *metamorphosis*, to use the technical expression. The life-history of the Frog (see p. 254) is an example of the same kind of thing, the essence of which consists in considerable modification in form and structure after the animal has been hatched out and has started a free independent existence. Insects differ very much among themselves as to the amount of metamorphosis, and the Cockroach exemplifies an order in which it is so slight as to be practically absent. The eggs are laid in horny capsules, each containing sixteen, and the just-hatched Cockroach closely resembles the adult, from which it chiefly differs in its smaller size and the absence of wings. As growth proceeds, the firm exoskeleton is not increased in size to suit the enlarging body as in a Mollusc, but is bodily thrown off or "moulted", a very common phenomenon among Arthropods. After some seven moults the adult size is attained.

Classification of Insects. — Considering that some 250,000 distinct species have been described, and that at least ten times this number are believed to exist, it will be realized that the classification of insects is likely to present some difficulties, espe-

cially as there are not the same obvious distinctions as are found in some other groups, *e.g.* Molluscs. Various subdivisions have been proposed, some of the modern ones being complex, but it will be the simplest plan to adopt here the comparatively old-fashioned grouping into nine orders, primarily based upon the characters of the wings, and which is mainly due to Linnæus. It will be enough for the present purpose if some of the commonest insects are mentioned, and sufficient detail given to enable the reader to refer an insect to its proper order.

Order 1. Bugs (HEMIPTERA).—Four wings, of which the front pair are often only membranous at the tips.

Order 2. Fringe-winged Insects (THYSANOPTERA).—Four wings, all very narrow and fringed.

Order 3. Flies (DIPTERA).—A single pair of membranous wings equivalent to the front pair of other insects.

Order 4. Moths and Butterflies (LEPIDOPTERA).—Four wings present, covered with scales.

Order 5. Beetles (COLEOPTERA).—Four wings, of which the front ones are converted into hard wing-cases, covering the membranous hind-wings, which during repose are folded transversely.

Order 6. Membrane-winged Insects (HYMENOPTERA).—Four membranous wings possessing but few nervures, and which cannot be folded up. Fore-wing larger than the hind.

Order 7. Net-winged Insects (NEUROPTERA).—Four membranous wings, with an elaborate net-work of nervures.

Order 8. Straight-winged Insects (ORTHOPTERA).—Four wings, of which the front pair are horny wing-cases, while the others are membranous and fold up in a fan-like manner when at rest.

Order 9. Wingless Insects (APTERA).—Primitive wingless insects. Insects belonging to other orders may have lost their wings by a process of reduction affecting one or both sexes.

Order 1.—BUGS (Hemiptera)

The English name given to the order is somewhat libellous, for though a number of repulsive forms are included here, others again are beautifully coloured and attractive objects. A typical species is outlined in fig. 203. There is considerable variation in the matter of *wings*, as both pairs may be much alike, or the fore-wings may be wing-cases, or again both pairs may be absent. In all cases the mouth-parts are converted into piercing and sucking organs, which, though much unlike the corresponding

parts of the Cockroach both in appearance and use, can be compared with them part for part. The narrow *upper lip* is pointed, and below it are the *mandibles*, but these, instead of being cutting-jaws, are long piercing stylets, grooved along their inner sides in such a way as, when applied together, to form a double tube down the lower half of which saliva can pass to the object pierced, while juices can travel along its upper half to the mouth. Outside, and close to the mandibles, are the *first maxillæ* in the form of two more stylets devoid of palps. The four stylets to-

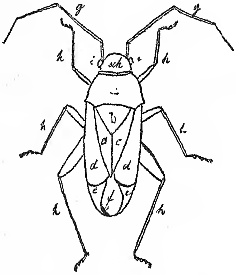


Fig. 203.—A typical Bug (*Capsus*)
a, *b*, First two segments of thorax; *c*, *d*, horny part of wing-covers; *e*, *f*, membranous part of wing-covers; *g*, antennæ; *h*, *h*, *h*, legs; *i*, eyes; *sch*, top of head.

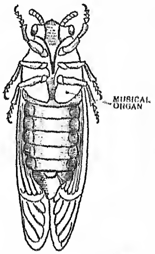


Fig. 204.—Cicada, seen from below

gether constitute an efficient piercing organ which can be protruded or drawn back at will by the action of special muscles, and it also forms a channel along which fluids can be conducted to the mouth, as just explained. The *second maxillæ*, including their palps, are fused together into a sheath for the piercing mouth-parts. In most cases the adult condition is attained without any large amount of metamorphosis.

The order is conveniently divided into two sub-orders; *i.e.* 1. Homoptera, in which the two pairs of wings are similar; and 2. Heteroptera, in which they are unlike.

1. *Homoptera.* — These all live upon the juices of plants, and their fore-wings are of uniform texture. *Cicadas* (fig. 204) are large, broad insects with membranous wings of considerable size, which may be opaque and brightly coloured. The antennæ are very small, and the head not only bears large lateral eyes, but also three simple eyes or *ocelli* placed in front and often gem-

like in appearance. The males are provided with musical organs on the under-side of the thorax, by which they are enabled to make a chirping sound, the well-known "song of the Cicada". The eggs are deposited in the branches of trees by means of a piercing organ with which the tail of the female is provided, and from them are hatched wingless larvæ, which dig into the ground by means of their fore-legs and subsist on the juices of roots, ultimately making their way up again and becoming adult. The larvæ may remain as such for a long period, in one North American species for seventeen years. Cicadas, of which there are very numerous species, inhabit the warmer parts of the earth, some of them being natives of South Europe.

Lantern-Flies and their allies make up a closely-related family, many members of which are beautifully coloured, but the species found in Europe (including Britain) are not highly endowed in this respect. The name "lantern-fly" has not been so far justified.

Most persons have seen, during the summer months, those frothy masses on plants to which the name "cuckoo spit" is vulgarly given. These enclose the larvæ of small insects belonging to this sub-order, and known as *Frog-Hoppers* on account of their leaping powers.

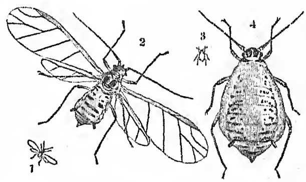


Fig. 205.—Cabbage Aphis (*Aphis brassicæ*)
1, 2, Male (natural size and enlarged); 3, 4, female (natural size and enlarged)

Plant-Lice, or *Green-Flies*, furnish other examples (fig. 205). The best-known forms are the little green aphides common on geraniums and other garden plants, and which, like their immediate allies, are distinguished by a complex life-history. The Vine-Louse (*Phylloxera vastatrix*) is a creature of the kind which does immense damage in vineyards.

The Cochineal Insect (*Coccus cacti*), on the other hand, is of economic importance. It is a native of Mexico and Central America, where it feeds upon cacti.

2. *Heteroptera.*—To the insects of this sub-order the name "bug" is properly applied. When wings are present, the front pair are transformed into wing-covers, the tips of which, however, remain membranous. Many of the species are distinguished by

a disagreeable odour, due to the secretion of certain glands which open on the under-side of the third segment of the thorax. Some are terrestrial and others aquatic. Many of the land bugs are not among the personal enemies of man, but feed on the juices of plants. These forms mostly escape the observation of those who are not entomologists, but the wingless blood-sucking bed-bug (*Cimex lectularius*) has an effective way of compelling attention that has rendered it the most widely known among its order. Even more odious are the small wingless forms known as *lice* which infest the bodies of human beings and many other animals, multiplying with astonishing rapidity. They are regarded as bugs which have become degenerate as a result of their parasitic habit. A typical example is the Head-Louse (*Pediculus capitis*), which feeds on the blood of the scalp, and lays its eggs on the hairs, to which they are firmly attached.

The *water-bugs* comprise a number of forms familiar to the student of fresh-water life, and to some extent known even to the casual observer. The *skaters*, which are often seen gliding about on the surface of the water, are of this kind, or, to speak more accurately, constitute a family allied both to land- and water-bugs. The Needle-Bug (*Limnobates stagnorum*), with long attenuated body and deliberate movements, is conspicuous among them. The Pond-Skater (*Gerris paludum*) has a stouter body and moves very rapidly. One genus (*Halobates*) is especially interesting in being a marine form living upon the surface of the sea even at great distances from land. This is remarkable, for though insects are exceedingly dominant as terrestrial forms, and are far from uncommon in fresh water, they are almost unrepresented in the marine fauna.

Water-bugs proper are inconspicuous insects distinguishable from their terrestrial allies by their extremely-reduced antennæ, and by the fact that they actually live in the water and not merely on it like the skaters. The *Water-Scorpions* are rapacious narrow-headed forms, in which the fore-legs are used for seizing their prey. The narrow tail-like prolongation which has suggested the common name is an arrangement connected with breathing, as will elsewhere be described. In some species there is a broad flat body (*e.g. Nepa cinerea*), while in others it is long and narrow (*Ranatra linearis*). Equally common are the broad-bodied *Water-Boatmen* (*Notonecta*), which, by means of their long hair-

fringed hind-legs, row themselves along upon their backs. Like the forms already mentioned, they prey upon small flies and the like.

Order 2.—FRINGE-WINGED INSECTS (Thysanoptera)

This is a very restricted order, including minute insects with suctorial mouth, long narrow body, well-developed slender antennæ, and four narrow wings with a fringe of hairs. The male is wingless. There is also a peculiarity about the feet, which end in bladder-like lobes.

Some of the species infest flowers, *e.g.* those of Elder; and the Corn Thrips (*Thrips cerealium*) (fig. 206) does a good deal of damage to crops.

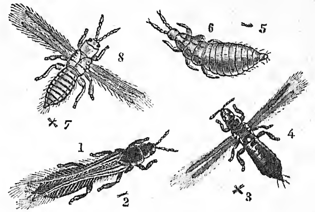


Fig. 206.—Corn Thrips (*Thrips cerealium*); 1, 2, female walking; 3, 4, female flying. Potato Thrips (*Thrips minutissima*); 5, 6, larva; 7, 8, female flying; 2, 3, 5, 7, natural size; 1, 4, 6, 8, enlarged.

Order 3.—FLIES (Diptera)

This is one of the largest orders of Insects, and includes not only innumerable *Flies*, but also those modified forms which are known as *Fleas*. As the scientific name indicates (Gk. *dis*, twice; *pteron*, a wing), only two wings are present (fig. 207). These are membranous, with comparatively few nervures, most of which run longitudinally, and they correspond to the fore-wings of other Insects. The hind-wings, however, have not entirely disappeared, but are represented by two club-shaped vestiges, which from their function are known as *balancers* (*halteres*).

The *mouth-parts* (fig. 207) are adapted for sucking, and often for piercing as well, but there are considerable differences from the arrangements which serve similar purposes in the Hemiptera. These structures are best developed in the females of such forms as Gnats, Mosquitoes, and Gad-Flies, where mandibles, maxillæ, and tongue are in the form of five piercing stylets, ensheathed in an imperfect tube formed by the labium and partly covered over by the long sharp labrum. Maxillary palps can be seen at the base of the proboscis. In the males of these forms, and both sexes of some members of the group, *e.g.* House-Fly (*Musca*

domestica), the piercing parts are much reduced and the mouth is purely suctorial.

Diptera undergo a complete *metamorphosis*. From the egg a limbless *larva* (maggot) is hatched, which becomes a *pupa*,

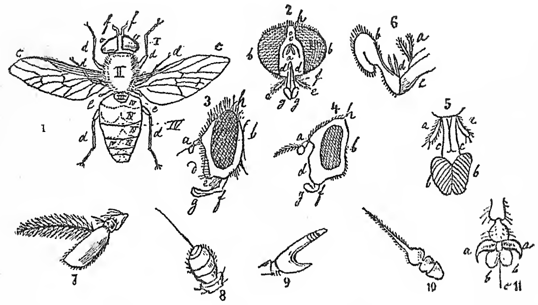


Fig. 207.—Structure of Flies (*Diptera*), enlarged to various scales

1, Parts of body: I, head; *o*, *o*, eyes; *f*, *f*, antennæ; II and III, thorax; *c*, *c*, wings; *e*, *e*, balancers; *d*, *d*, *d*, legs; IV, abdomen, with segments indicated. 2, Head (front view): *a*, antennæ; *b*, *b*, eyes; *c*, forehead; *d*, *d*, upper lip; *e*, *e*, palps; *f*, body of proboscis; *g*, *g*, suctorial flaps of proboscis. 3, 4, Head (side view): *a*, antennæ; *b*, eyes; *d*, lower part of face; *e*, palp; *f*, proboscis; *g*, suctorial flaps of proboscis; *h*, crown of head. 5, Proboscis (front view); *a*, *a*, palps; *b*, *b*, suctorial flaps; *c*, *c*, stalk. 6, Proboscis (side view): *a*, palps; *b*, suctorial flaps; *c*, stalk; *d*, mandibles. 7–10, Antennæ of various flies. 11, Foot: *a*, *a*, claws; *b*, *b*, adhesive lappets; *c*, bristles.

that may or may not possess the power of movement, and from which the adult insect or *imago* is developed. As the adult does not grow in size, the various-sized Flies which are often to be seen on windows and elsewhere are different species, and not, as often supposed, different stages in the growth of the same species.

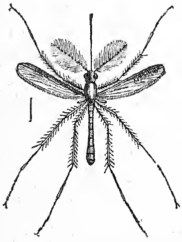


Fig. 208.—Common Gnat (*Culex pipiens*), much enlarged

The Common Gnat (*Culex pipiens*) (fig. 208) is a representative of a very large family in which the females are distinguished by their blood-sucking propensities, while the males are supposed to live upon the juices of plants. The body is slender, the legs long, and the antennæ are well-developed, those of the male being beautiful plume-like objects. The eggs are laid on the surface of ponds, &c., a considerable number being agglutinated together

into a sort of raft. The *larvæ* which hatch out from them (fig. 209) look something like little red worms with large heads, and they possess a special breathing arrangement in the form of two tubes, each with a stigma at its tip, projecting from the hinder end of the body. The favourite position of the larva is suspended head downwards close to the surface, with the ends of these tubes just projecting above water, and so enabling breathing to

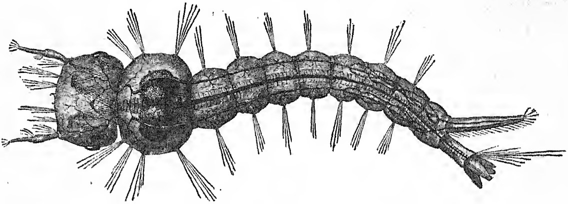


Fig. 209.—Larva of Common Gnat (*Culex pipiens*), greatly enlarged

be carried on. After several moults, the larva becomes a *pupa*, at the front end of which the wings, legs, and antennæ of the adult can be dimly made out under the skin. From each side of the thorax a breathing-tube projects, and these are used like those of the larva, except that owing to their position the animal is suspended tail downwards. The pupa is active, and swims by jerking its tail. Examination from time to time of almost any old rain-water butt will enable one to trace the successive stages of the life-history of the Gnat, the final one of which is reached by the splitting of the pupal skin down the middle of the back, making a rent from which the adult Gnat makes its exit, being floated up meanwhile by the buoyancy of its investments.

Midges resemble Gnats in many particulars, and pass through a somewhat similar life-history; but they are much smaller, and it is only the females of some species which possess mouth-parts adapted for blood-sucking. The small black Midge (*Ceratopogon*) which is so troublesome in the summer months is one of these forms. The Plumed Midge (*Chironomus plumosus*), of which hosts may be seen dancing together any summer evening, is a well-known species, distinguished by the great beauty of the antennæ in the male.

The *Crane-Flies* are much larger insects, of which the Daddy-Long-Legs (*Tipula oleracea* and other species) is known to all. The peculiarly long legs are especially useful in enabling the animal to progress rapidly through grass. The eggs are laid in meadows, and the larvæ feed upon the roots of grasses.

All the preceding are distinguished by comparatively long antennæ, but in numerous families these appendages are very short. Well-known examples are the Horse-Stinger or Cleg (*Tabanus bovis*), a large speckled insect, the bite of whose female has been experienced by most of us in walking through woods; the notorious cattle pests called *Bot-Flies* (*Hypoderma bovis*, ox-bot; *Œstrus ovis*, sheep-bot; *Gastrophilus equi*, horse-bot); and the Tsetse-Fly (*Glossina morsitans*). Here, too, belong the Blue-Bottle (*Musca vomitoria*), House-Fly (*Musca domestica*), and their allies, constituting a family in which the piercing mouth-parts, as found in many of the preceding, have been reduced to mere vestiges, while a complex sucking proboscis is present, formed chiefly by the labium. The Fly's tongue is one of the commonest, most beautiful, and at the same time most complicated, of microscopic objects.

The *Fleas* are doubtfully associated with the Diptera as degraded forms living parasitically on the bodies of warm-blooded animals. The mouth-parts are modified for piercing and sucking, but present considerable differences from the arrangement described for the Gnats, &c. (p. 355). Wings are absent, and so are compound eyes, the organs of vision consisting only of a simple eye on each side. The long strong hind-legs are associated with great powers of leaping. The Common Flea (*Pulex irritans*) is not, as often imagined, the same species as those infesting cats, dogs, and other domestic animals. It appears, indeed, that there are very numerous sorts of Fleas associated with different Mammalia, even Bats being attended by their own peculiar species.

Order 4.—Moths and Butterflies (Lepidoptera)

The insects of this order are, in the vast majority of cases, so characteristic-looking that they can be recognized at first sight mainly because they possess two large pairs of wings covered with minute variously-shaped scales (fig. 210), easily rubbed off as what is popularly called the "dust" of the wing. The presence of

these scales gives rises to all sorts and combinations of colours, often of extreme beauty. The male and female of the same species are often very different in appearance.

The *head*, which is well-marked off from the thorax, bears long antennæ and prominent compound eyes, while its mouth-parts are converted into a long *proboscis*, carried rolled up into a spiral when not in use (fig. 211). This organ is used to suck up the nectar of flowers or, in some cases, liquid matter of a less savoury kind, but differs entirely in structure from the corresponding organ of a Fly. The *upper lip* is inconspicuous, and the *mandibles* have disappeared altogether, while the *second maxillæ* are fused into a small plate bearing two conspicuous palps. The sucking part is formed entirely from the much-elongated *first maxillæ*, each of which is a long jointed structure grooved deeply on its inner side, so that when approximated to its fellow a tube is formed, the firmness of which is often enhanced by a series of interlocking hooks.

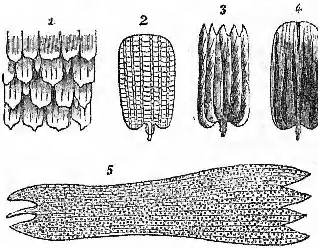


Fig. 210.—Scales from Wings of various Butterflies (greatly enlarged)

The *thorax* bears not only the wings, but three pairs of weak legs, and is fairly well marked off from the *abdomen*, which is generally elongated, but may either be very slender or else broad according to the species.

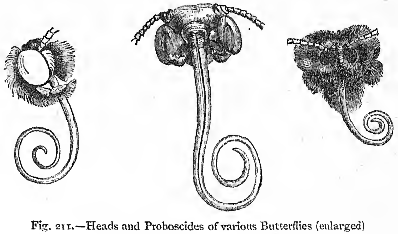


Fig. 211.—Heads and Proboscides of various Butterflies (enlarged)

The *life-history* of a Moth or Butterfly furnishes a good example of complete *metamorphosis*. The eggs are laid upon some special food-plant, and the larvæ which hatch out from them are ravenous *caterpillars* which feed upon vegetable matter or, more rarely, other substances. The head is provided with

an extremely short pair of antennæ, a group of simple eyes on each side, and biting mouth-parts. The cylindrical trunk is composed of eleven segments, the first three of which bear jointed legs corresponding to those of the adult; and besides this, from one to five of the other segments possess stumpy pro-legs which have sucker-like ends. Those at the posterior end of the body are often modified in various ways.

Caterpillars vary much in size, colour, and other characters, among which may be mentioned presence or absence of hairs, some being smooth and hairless, and others so hirsute as to have earned the popular name of "woolly bears". After leading a life entirely devoted to continuous feeding for a period varying from weeks to years, during which time the skin is frequently moulted as the body increases in size, the caterpillar becomes lethargic and passes into the quiescent pupa stage, constituting what is generally called a *chrysalis*. A continuous horny covering invests body and limbs alike, beneath which the parts of the perfect insect can be dimly traced. Innumerable methods of concealment and protection ward off to some extent the attacks of enemies during this helpless period. In some cases the chrysalis is to be found above-ground suspended by a silken cord, or fastened to some object by a girdle of the same material, in which cases its colour commonly harmonizes with the surroundings and renders it inconspicuous. Other chrysalides are sheltered underground, and others again are to be found within cocoons, of which the silkworm is the most familiar illustration.

The last stage is reached when the perfect insect or *imago* issues from the chrysalis at a time dependent upon favourable conditions of temperature and various other factors, such, *e.g.*, as a suitable state of the particular food-plant upon which the eggs are laid.

The most convenient way of subdividing Lepidoptera is into the two groups of (1) Butterflies (Rhopalocera) and (2) Moths (Heterocera), of which the latter include a very much greater number of species, there being in Britain, for example, over 1900 sorts of Moths as against between sixty and seventy species of Butterflies.

1. *Butterflies* (Rhopalocera).—Butterflies for the most part are active in the daytime, especially during sunny weather. They can readily be distinguished from Moths by the antennæ,

which are club-shaped, and in most cases by their habit of shutting the wings together over the back when they alight. As the wings are far less brilliantly coloured on their under sides, which are then the only surfaces visible, a very efficient means of protection is afforded. The body is comparatively slender, and the demarcation between thorax and abdomen well-marked. The eggs are often sculptured in a way which renders them extremely beautiful microscopic objects, and the caterpillars may be naked, slightly hairy, or covered with branching spines. They posses five pairs of pro-legs. The angular chrysalis is sometimes simply suspended by the tail, or it may be fixed head upwards both by the tail and by a silken girdle round the thoracic region. It is frequently marked with metallic patches, to which the name chrysalis is due (Gk. *chrysos*, gold).

Butterflies are found in all parts of the world, and some common examples may here be mentioned.

The *Fritillary Family* is at once the largest and most widely distributed group of Butterflies. They are distinguished by the remarkable fact that their fore-legs are so much reduced as to be useless for walking purposes. Among British species are the Great Tortoiseshell (*Vanessa polychloros*) (fig. 212), the Small Tortoiseshell (*V. urticæ*), the Peacock Butterfly (*V. Io*), and the Red Admiral (*V. Atlanta*), in all of which the larvæ feed on nettles: the Painted Lady (*V. cardui*), an almost cosmopolitan species, of which the larvæ feed on thistles; and the Purple Emperor (*Apatura Iris*), a much rarer and finer insect, with a predilection for carrion. Closely related to these is the Resplendent Ptolemy (*Morpho Neoptolemus*), a gorgeous tropical Butterfly. *Morpho cypris* is brilliant blue, streaked with white.

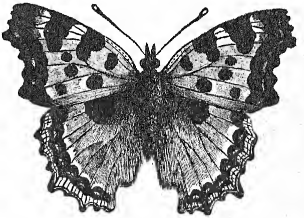


Fig. 212.—Great Tortoiseshell Butterfly (*Vanessa polychloros*)

The family of *Whites* includes several British species which are perhaps more familiar than any other, partly on account of their conspicuous colour and partly owing to the ravages which their larvæ perpetrate in the kitchen-garden. The abdomen is enveloped by the basal part of the hind-wings. This family is

almost universally distributed, and British species are:—the Black-veined White (*Aporia cratægi*), the Large White or Cabbage Butterfly (*Pieris brassicæ*), the Small White or Garden White (*P. rapæ*), and the less common Green-veined White (*P. napi*); the beautiful little Orange Tip (*Anthocharis cardamines*), so named from the markings on the wings of the male; and the handsome Brimstone Butterfly (*Gonopteryx rhamni*), with angular outlines to the wings.

The *Swallow-tailed Butterflies*, which rival the Whites in their range of distribution, include numerous gorgeous tropical species, and the common name has reference to the slender "tail" into which the posterior margin of each hind-wing is often produced. The type genus, *Papilio*, comprises over 300 species, including our largest British form (*Papilo machaon*), now limited to the fen district. The huge Bird-winged Butterflies (*Ornithoptera*) of the Malay region belong to the same family, though they are without tails.

The family of *Blues* and *Coppers* is represented in all parts of the world, many of the tropical species being exceedingly beautiful. Two common British species of small size may be mentioned in illustration: the Common Blue (*Polyommatus alexis*) and the Small Copper (*Chrysophanus phlæas*).

2. *Moths* (Heterocera).—Moths are mostly nocturnal forms, differing from Butterflies in many particulars, among which may be mentioned the absence of knobs on the ends of the antennæ, and the habit of reposing with the wings spread out horizontally or folded round the body. The body is often much thickened, and the demarcation between thorax and abdomen is not well marked. In most cases there is a special "hook-and-eye" arrangement for uniting the wings during flight, and consisting of one or more bristles at the root of the hind-wings, which fit into a socket on the under side of the adjoining part of the fore-wings. The larvæ are either naked or more or less hairy, and may possess as many pro-legs as those of Butterflies, or fewer. The pupæ are rounded in outline, usually enclosed in a cocoon, and in many cases concealed underground.

The group may be divided into (I) Large Moths, including Hawk-Moths, Clear-Wings, Spinners, Owlets, and Loopers; and (II) Small Moths, embracing Leaf-Rollers, Leaf-Miners, Plume-Moths, and many others.

I. *Large Moths*, as the name indicates, are usually of considerable size, and agree with the Butterflies in the following characters:—The wings are elaborately veined, and the larvæ, which feed upon leaves, have downwardly-directed heads, and, usually, a curved line of horny bristles near the tip of each pro-leg. The abdomen of the pupa is devoid of transverse rows of spines.

Hawk-Moths are large swiftly-flying insects with a very long proboscis, suited for draining honey from flowers (such as honeysuckle) possessing a very long tubular spur. The caterpillars have smooth brightly-coloured skins, and are provided with five pairs of pro-legs, while a horn-like projection is found on the upper surface, near the hinder end of the body. The pupæ are found underground, enclosed in cocoons of earth. British examples are the Death's-Head Moth (*Acherontia Atropos*), with markings on the upper side of the thorax looking like a skull and cross-bones, and the Privet Moth (*Sphinx ligustri*). The larva of a common European species, the Pine Hawk-Moth (*Sphinx pinastri*), is very destructive to pine-trees.

The *Clear-Wings* are remarkable from the absence of scales on the wings, owing to which, and the nature of their markings, they resemble wasps, &c., this being no doubt a protective arrangement. The Hornet Clear-Wing (*Trochilium apiforme*) is a typical native species.

Spinners are large clumsy moths, clothed with abundant hair, and provided with a short proboscis. The colours are dull, and the two sexes differ considerably in appearance, *e.g.* in the character of the antennæ, which are plume-like in the male, and thread-like in the female. The caterpillars are more or less hairy, and before becoming pupæ spin cocoons, which may be entirely of silk, or contain a number of cast hairs in addition. One of the most beautiful British species belongs here, the Emperor Moth (*Saturnia carpini*), with an eye-like marking on each wing, and the caterpillar, abundant on heather, of emerald-green with pink tubercles. The spread of wing may be as much as 3 inches, but this appears small by comparison with exotic species, especially the Atlas Moth (*Attacus atlas*), in which the wings measure about a foot across. Among other native species may be mentioned the large Goat Moth (*Cossus ligniperda*), with wood-boring larva; the Tiger Moth (*Arctia caja*); the Puss Moth (*Cerura vinula*), with an extraordinary-looking caterpillar; the Buff-Tip (*Pygæra

bucephala); the Pale Tussock-Moth (*Dasychira pudibunda*); the Lackey (*Clisiocampa neustria*); and the Oak Eggar (*Lasiocampa quercus*). Spinner Moths, however, are best known from the Silkworm Moth (*Bombyx mori*), a native of China introduced into many countries for the sake of its silk.

Owlets form the largest group of the Lepidoptera, and include dull-coloured species, with comparatively small fore-wings, each of which is characteristically marked with a couple of spots, one round and the other somewhat kidney-shaped. The larvæ of many species, as "surface caterpillars", do much harm to crops, and the pupæ are found underground, enclosed in earthen cocoons. Common British species are: the Common Wainscot Moth (*Leucania pallens*), Yellow Underwing (*Triphæna pronuba*, fig 213), the Heart-and-Dart Moth (*Agrotis exclamationis*), and the Silver Y (*Plusia gamma*).

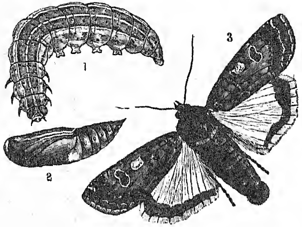


Fig. 213.—Yellow Underwing (*Triphæna pronuba*) 1, Caterpillar; 2, chrysalis; 3, adult.

Loopers are moths of slender build, with broad thin wings and small antennæ. The caterpillar has but two pairs of pro-legs, placed right at the posterior end of the body, and this necessitates a curious mode of locomotion, which gives the name to the group. The body is stretched out to its full length, and then, while holding firmly by means of its three ordinary legs, the pro-legs are brought up and fixed close behind them, the body being thus thrown into a loop. Now, holding firmly by the pro-legs, the body is stretched forwards, and the ordinary legs attach themselves again. By repeating these manœuvres the caterpillar can move rapidly along in a curious looping fashion. When at rest the larva has a curious habit of attaching itself by the pro-legs, and stretching out the body at an angle to the surface of attachment, at the same time stiffening itself. This position can be retained for hours, and the caterpillar looks so like a short bare twig that it is rendered extremely inconspicuous to its enemies. Common British species are: the Brimstone Moth (*Rumia cratægata*), the Magpie or Currant Moth (*Abraxas grossulariata*), the Winter Moth (*Cheimatobia brumata*), and the Chimney Sweeper (*Tanagra chærophyllata*).

II. The *Small Moths*, as their name indicates, differ from the members of the other group in size, and usually possess long slender antennæ. The caterpillars, which burrow in vegetable substances or conceal themselves by rolling leaves together, have their heads forwardly directed, and a circlet of spines near the tip of each pro-leg, of which there are five pairs. The pupæ are generally distinguished by the presence of transverse rows of spines on the upper side of the abdomen. Among the groups may be mentioned Leaf-Rollers, Leaf-Miners, and Plume-Moths.

Leaf-Rollers are so named from the habit many of the larvæ have of feeding either between leaves which they have glued together with silk, or else inside individual leaves which have been rolled up and fixed in a similar way. Common British species are: the Green Oak Moth (*Tortrix viridana*), and the Codlin Moth (*Carpocapsa pomonella*), of which the caterpillar tunnels within the fruit of apples and pears.

The *Leaf-Miners* constitute a large group of small and very small moths with narrow hair-fringed wings. One of the prettiest species is the Little Ermine-Moth (*Hyponomeuta padella*), the larvæ of which keep together in companies as hatched out, and spin a considerable amount of web. They devastate the leaves of hawthorn, sloe, &c. Another beautiful but extremely small form is the Brown Dolly (*Lithocolletis corylella*), the caterpillars of which mine in hazel leaves. Unfortunately, however, the best-known are the different species of Clothes Moth (*Tinea pellionella, Trichophaga tapetzella*) (figs. 214 and 215).

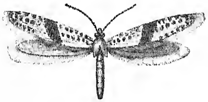


Fig. 214.—Adult stage of a Clothes Moth (enlarged)

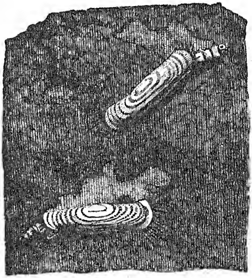


Fig. 215.—Larvæ of a Clothes Moth (enlarged)

The *Plume-Moths* are a comparatively small group of pretty little long-legged moths with wings split up into a varying number

of plume-like portions. Common British species are: the Common Plume-Moth (*Pterophorus pterodactylus*) and the Twenty-Plume Moth (*Alucita polydactyla*).

Order 5.—Beetles (Coleoptera)

This is by far the largest order of insects, and includes forms which are for the most part easily recognizable, though the name of "beetle" is popularly but erroneously given to members of other groups, *e.g.* to the Cockroach. The wings of an average beetle are of very characteristic appearance and nature, as may be seen by examining such a typical example as the little Lady-Bird (*Coccinella*), which is at once known by its conspicuous colouring of black spots on a red ground (fig. 216). At first sight such an insect appears to have no wings at all, but every child who has induced a lady-bird to "fly away home", by persuasive shoves added to an alarming story of domestic calamity, knows better than that. The fore-wings are not, however, organs of flight, but horny wing-covers or *elytra* (see p. 345) stretching back over the abdomen, and abutting against one another in the middle line. They protect the membranous hind-wings (fig. 217), which, when not in use, are hidden beneath them, and are not only folded longitudinally, as in a Cockroach, but also transversely, a very characteristic feature for beetles. The *head* is large, and bears a pair of compound eyes, and two antennæ varying greatly in shape according to the

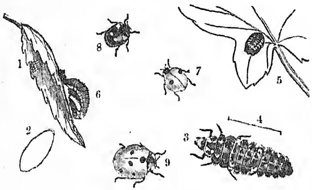


Fig. 216.—Lady-Birds

1, Cluster of eggs; 2, egg (greatly magnified); 3, larva (magnified); 4, actual length of same; 5, 6, pupæ; 7, 8, varieties of Two-spotted Lady-Bird (*Coccinella bipunctata*); 9, Seven-spotted Lady-Bird (*C. septempunctata*).

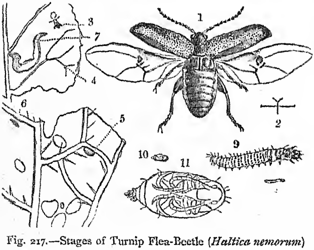


Fig. 217.—Stages of Turnip Flea-Beetle (*Haltica nemorum*)

1, Adult (enlarged), showing wing-covers and wings spread out; 2, 3, natural size of same; 4, 5, eggs (enlarged); 6, 7, burrows of larvæ (enlarged); 8, 9, larva (natural size and enlarged); 10, 11, pupa (natural size and enlarged).

species. The *mouth-parts* are adapted for biting, and are built on the same plan as in the Cockroach (see p. 345), but with many differences in detail, as seen, for example, in the more complete fusion which has taken place between the two second maxillæ, and in the fact that these jaws are much reduced. The *life-history* of a beetle (figs. 216 and 217) exhibits a complete *metamorphosis*, the larva being a grub possessed, in most cases, of three pairs of legs corresponding with those of the adult, and becoming a pupa differing from that of a moth or butterfly as regards the limbs and wings, which form prominent projections instead of being merely indicated beneath the continuous horny covering.

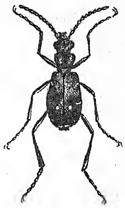


Fig. 218.—Green Tiger-Beetle (*Cicindela campestris*)

Only a few common species, representing important families, can be mentioned here.

Tiger-Beetles are very active, predaceous insects, including somewhere about a thousand species, and distributed generally throughout the world, though most abundant in the tropics. A common British form is the Green Tiger-Beetle (*Cicindela campestris*) (fig. 218), common on sandy banks, and distinguished by the beautiful golden-green colour of its upper surface. The larva is provided with enormous curved mandibles, and excavates a vertical burrow in which it lies in wait for prey.

Ground-Beetles are also predaceous, and even more widely distributed than the Tiger-Beetles, though much more numerous, there being some eleven thousand species. They are least abundant in the tropics. A large and well-known British species, the Violet Ground-Beetle (*Carabus violaceus*), so named on account of the dark violet sheen exhibited by its upper surface, is common in fields and gardens, and may also be found in houses, where it preys upon cockroaches and crickets.

Water-Beetles include ravenous forms which resemble ground-beetles in many respects, but are adapted to an aquatic life. The largest British form is the Great Water-Beetle (*Dytiscus marginalis*) (fig. 219), and here may also be included the Whirligig Beetle (*Gyrinus natator*), which almost everyone must have noticed twirling round and round at the surface of the water in ponds and ditches.

Rove-Beetles, possessing broad heads, narrow bodies, and short

elytra, agree with the preceding families in their carnivorous habits. Most familiar perhaps in Britain is the Devil's Coach-Horse (*Ocypus olens*), which has the curious habit of turning up its tail when molested (fig. 220).

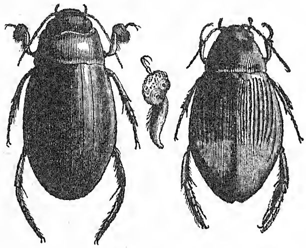


Fig. 219.—Great Water-Beetle (*Dytiscus marginalis*)

Male to left, and female to right. Part of the fore-foot of male (enlarged) is represented in centre to show the pad and suckers with which it is provided.

The *Scarabs* rival the ground-beetles in number of species and include many large and handsome forms, distinguished by characteristic antennæ, of which the last few joints are so broadened out that when expanded they look like a small fan. The adults and larvæ feed either upon vegetable substances or on dung. Here belongs the largest British species, the Stag-Beetle (*Lucanus cervus*), in which the mandibles of the male resemble antlers. The largest-known beetles are not very distantly related, and forms commonly seen in museums are the Hercules-Beetle (*Dynastes hercules*) from tropical America, and the Goliath-Beetle (*Goliathus Druryi*), the male of the former species sometimes exceeding 5 inches in length, as against the 3 inches of our Stag-Beetle. One of the commonest British dung-beetles is the Dumble-Dor (*Geotrupes stercorarius*), a sluggish insect of bluish-black colour, often seen crawling slowly along country roads. An allied genus includes the Sacred Scarab (*Scarabæus sacer*) of the Egyptians.

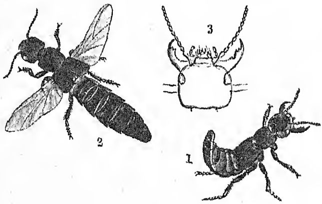


Fig. 220.—Devil's Coach-Horse (*Ocypus olens*)

1, Standing with turned-up tail; 2, flying; 3, head enlarged, to show eyes, antennæ, and jaws.

The *Chafers* constitute a large and well-known group of the Scarab Beetles. Common British species are the Cockchafer (*Melolontha vulgaris*), the green-and-brown Garden Chafer (*Phyllopertha horticola*), and the beautiful golden-green Rose Chafer (*Cetonia aurata*) (fig. 221).

Weevils are small beetles with long snouts which do great damage to timber, fruit, and grain. Some ten thousand species are known. A common British form is the Nut Weevil (*Balaninus glandium*), which lays its eggs in hazel-nuts and acorns, upon the kernels of which the larvæ feed when they have hatched out. Two species of Weevil are represented in fig. 222.

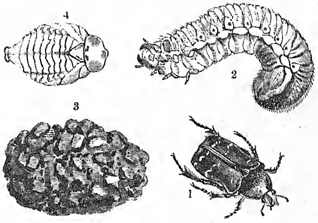


Fig. 221.—Rose Chafer (*Cetonia aurata*)
1, Adult; 2, larva; 3, cocoon; 4, pupa.

Lady-Birds (fig. 216) are among the insects which are of great use to man, as they prey upon plant-lice, to which their larvæ are a veritable terror. Over a thousand species are known distributed throughout most regions of the globe. The commonest British species are the Seven-spotted Lady-Bird (*Coccinella septempunctata*) and the Two-spotted Lady-Bird (*C. bipunctata*), distinguishable by the number of black spots upon the red elytra.

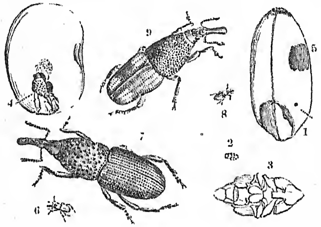


Fig. 222.—Corn-Weevil
1, Grain of wheat, showing the punctured hole; and 5, the exit of the perfect weevil. 2, Pupa (natural size); 3, magnified. 4, Grain of Indian corn, with weevil inside. 6, 7, Corn-Weevil (*Calandra granaria*), natural size and magnified; 8, 9, Rice-Weevil (*C. oryzæ*), natural size and magnified.

Order 6.—Membrane-winged Insects (Hymenoptera)

This very large order contains many thousand described species, including among many others the different kinds of bee, wasp, and ant. Not a few live in communities of exceedingly complex organization, and these display so much intelligence that there is much to be said for the view that the order is the highest among insects. Four membranous wings (fig. 223) are present, whence the technical name (Gk. *hymēn*, membrane; *pteron*, wing); they possess comparatively few nervures, and are not folded during repose. It will be remembered that in most Moths there is a "hook-and-eye" arrangement for coupling the wings together

during flight. In the present order the same end is brought about by a more perfect contrivance. On the front margin of the hind-wing, which is smaller than the fore-wing, a series of hooks will be found which catch on to a fold on the hinder margin of the latter, and due to a curling up of the edge. The complex *mouth-parts* are adapted for both biting and licking, as may be seen by careful examination of a hive-bee (fig. 223). The triangular *upper lip* will here be seen to overlap a pair of powerful *mandibles*, under which come the long *first maxillæ*, provided with cutting-blades and palps (in this species very small), and lastly follow the fused *second maxillæ*. These are drawn out into a slender tongue-like structure suited for licking, and grooved for the conduction of liquid.

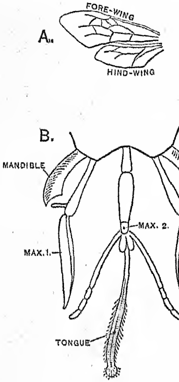


Fig. 223.—Structure of Hymenoptera

A, Wings of a bee. B, Diagram of mouth-parts of Honey-Bee (*Apis mellifica*), much enlarged and widely separated.

Female Hymenoptera are either provided with a sting at the posterior end of the body, or else with a piercing arrangement (ovipositor) for making holes in which to lay the eggs. The *metamorphosis* is particularly well-marked. Larvæ resembling caterpillars, or it may be of worm-like appearance, hatch out from the eggs, which have previously been deposited in plants, the bodies of other insects, or sometimes in specially-constructed chambers (as in bees). The pupæ are generally enclosed in a cocoon of silk, and, as in beetles (see p. 366), their limbs project freely.

Three sub-orders are recognized:—1. Plant-Eaters, 2. Insect-Eaters, and 3. Stinging Hymenoptera.

1. *Plant-Eating Hymenoptera* include the *Saw-Flies* and *Wood-borers*, of which some thousand species have been described. The ovipositor of the female is adapted for boring holes in plants, and the abdomen does not in either sex narrow to a stalk at its base, as in a wasp or ant. The mouth-parts are not so specialized as in the example taken above. The larvæ resemble caterpillars, for which indeed they are often mistaken, but may easily be distinguished by the presence of more than five pairs of pro-legs in

addition to the three pairs of legs proper, while a caterpillar never has more than five pairs of pro-legs, and often fewer. Nor do these pro-legs possess, like those of most caterpillars, a curved row or circlet of minute bristles near their tips. Further, a "false" caterpillar has a rounded instead of a flattened head, moves its abdomen vertically up and down when disturbed, and curls it up in a state of rest.

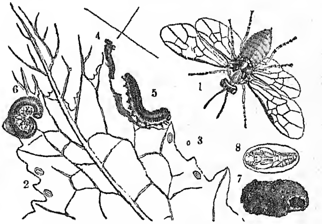


Fig. 224.—Turnip Saw-Fly (*Athalia spinarum*

1, Adult female, enlarged (natural size represented to left of it); 3, 2, Eggs (natural size and enlarged); 4, 5, 6, larvæ; 7, cocoon; 8, pupa in cocoon.

The "saw" of a saw-fly consists of two curved saw-like blades protected by sheaths when not in use. The blades are worked alternately backwards and forwards, and the eggs slip down between them into the incision formed. A common species is the Turnip Saw-Fly (*Athalia spinarum*) (fig. 224), the larvæ of which ravage the crop after which the insect is named.

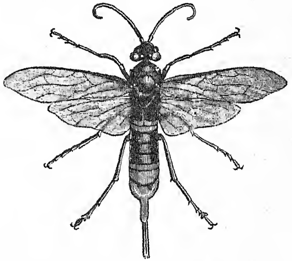


Fig. 225.—Large Wood-Borer or Wood-Wasp (*Sirex gigas*)

In a *Wood-Borer* the blades corresponding to the saws of a saw-fly are fused together into a boring spine, which is used like an auger. A conspicuous species, not infrequently seen in this country, is the Large Wood-Borer (*Sirex gigas*) (fig. 225), also called Wood-Wasp from the transverse black and yellow bandings of its body. The female bores holes in pine-trees in which to lay her eggs, and from these, eyeless grubs hatch out which only possess the three pairs of ordinary legs. These larvæ burrow in the timber by means of their strong mandibles, and later on become pupæ enclosed in cocoons formed from silk mixed with fragments of wood.

2. The *Insect-Eating Hymenoptera* are so named because the larvæ are commonly parasitic within the larvæ of other insects,

though to this there are many exceptions. The abdomen is stalked, and the female is provided with a piercing ovipositor by which punctures are made for the reception of eggs. The larvæ are pale legless grubs. It is stated as probable that the sub-order contains 20,000 species or even more, which means an innumerable host of enemies to other insects. The Winter Moth (*Cheimatobia brumata*), for example, is attacked by no less than 63 different kinds of Hymenoptera belonging to this group. Two leading families are the Gall-Flies and Ichneumon-Flies.

Gall-Flies are so named because they puncture plants for egg-laying purposes, with the result that the wounded parts give rise to those peculiar excrescences known as "galls", of which the spherical brown bodies called "King Charles's oak-apples", common on the oak, are known to everyone who has been in the country. This tree indeed is peculiarly liable to the attacks of different species of gall-fly, which lead to the production of galls of totally different appearance, some resembling currants, others looking like little cones, and others again being in the form of circular scales ("oak spangles") on the backs of the leaves.

We may mention, as a specific example of a gall-fly, the form *Rhodites rosæ*, which is responsible for the tufted red galls often seen on wild rose-trees and known as rose-bedeguars or "old man's beard".

Ichneumon-Flies constitute a family of which nearly 6000 species have been described, over 1200 of these being British. The larvæ usually attack caterpillars, in or on which the eggs were laid by the parent. Insects of other kinds, and even spiders, are, however, attacked by some of the species. It was till recently thought that the parasite subsisted by devouring the non-vital parts of its host, but it is more probable that it simply absorbs the blood of the caterpillar through its skin.

One common ichneumon-fly (*Microgaster glomeratus*) lays its eggs in the caterpillar of the common white Cabbage Butterfly, within which they hatch out. When the unfortunate host has reached its full term of growth, and should be ready to turn into a chrysalis, it is too much enfeebled to do so. The unwelcome guests now bite their way out of the caterpillar and become pupæ on their own account, and it is no uncommon thing to find a dead caterpillar which has fallen a victim to ichneumon larvæ side by side with a little heap of pupæ belonging to these foes. Another

species (*Hemiteles melanarius*) (fig. 226) lays its eggs in the chrysalis of the Green-veined White.

3. *Stinging Hymenoptera* are generally distinguished by the presence of a sting in the female, which takes the place of the ovipositor found in the forms so far mentioned. Special cells are usually constructed in which the helpless larvæ are reared. As in the last sub-order, the abdomen is attached by a stalk, which may be extremely slender. Ants, Wasps, and Bees are here included, many of which live in social communities, the politics of which will be dealt with in another part of this book, and which in itself would require an entire volume to do it justice.

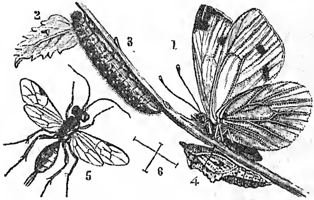


Fig. 226.—The Green-veined White (*Pieris napi*), and an Ichneumon-Fly (*Hemiteles melanarius*), which lays its eggs in the chrysalis of the same. 1, 2, 3, 4, Adult female, eggs, caterpillar, and chrysalis of the butterfly; 5, adult female of the ichneumon-fly, of which natural size is shown by 6.

More than a thousand species of *Ants* have been described, of which over thirty are British. Among these are the large red Wood Ant (*Formica rufa*), the large "ant-hills" of which may be seen in fir-woods, the Slave Ant (*Formica fusca*), the Slave-making Ant (*Polyergus rufescens*), the Black Ant (*Lasius niger*), the Yellow Ant (*Lasius flavus*), and the Solitary Ant (*Mutilla Europæa*).

Sand-Wasps dig tunnels in the ground, at the end of which their eggs are laid. Many of them make a curious provision for their larvæ in the shape of insects, caterpillars, grubs, or it may be spiders, which they have stung in the nerve-cord so as to render them powerless without actually killing them. Among British forms may be mentioned the Path-Wasp (*Pompilius exaltatus*), which stores up spiders; the Common Sand-Wasp (*Ammophila sabulosa*), which buries caterpillars; and the Fly-storing Sand-Wasp (*Mellinus arvensis*), which does the same to flies.

Wasps are either solitary or social, the most familiar example of the latter kind being the Common Wasp (*Vespa vulgaris*), which, as is well known, constructs nests in banks and other places. The combs which these contain are constructed of a kind

of paper formed by working up bark and decayed wood to a sort of pulp. Another and larger social wasp is the Common Hornet (*Vespa crabro*), in which the front part of the body is of a reddish colour. Of solitary species the Mud-Wasps (*Odynerus parietum* and others) may be mentioned, which construct their cells of mud in the crevices of walls, the hollow stems of plants, and other places.

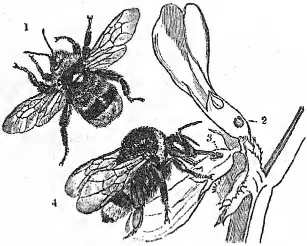


Fig. 227.—Bees and Flowers of Broad-Bean

1, Wood-Bee (*B. leucorum*). 2, 2, Holes cut by bee in bases of flowers. 4, Humble-Bee (*Bombus terrestris*) extracting nectar through one of the holes.

Bees, like Wasps, include social and solitary species, the Hive-Bee (*Apis mellifica*) furnishing a good example of the former sort, that also includes the Humble-Bee (*Bombus terrestris*) (fig. 227), which makes its nests in the ground. In solitary bees the labium is much shorter than in the Hive-Bee. They belong to numerous genera, and include Leaf-Cutter Bees, which make their cells from pieces of leaf, Carpenter-Bees (*Xylocopa*), which cut out cells one above another in the trunks of trees, and Flower-Bees (*Anthophora*), forms which look something like humble-bees.

Order 7.—Net-winged Insects (Neuroptera) (fig. 228)

This order, which is much smaller than some of those already dealt with, contains a great variety of forms which differ very widely in appearance. The most typical members of the order possess four membranous wings exhibiting an elaborate net-work of nervures, quite unlike the simple arrangement characteristic of Hymenoptera. The mouth-parts are usually adapted for biting. Eleven families are recognized, arranged in five groups; *i.e.*—1. Dragon-Flies, May-Flies, and Stone-Flies; 2. Flat-winged Neuroptera; 3. Caddis-Flies; 4. White Ants and Book-Lice; 5. Biting-Lice.

1. *Dragon-Flies*, *May-Flies*, and *Stone-Flies* all possess the four typical wings and pass through an aquatic larval stage. *Dragon-Flies* are among the most beautiful objects to be seen in the course of a summer walk in the country. The four large wings are of

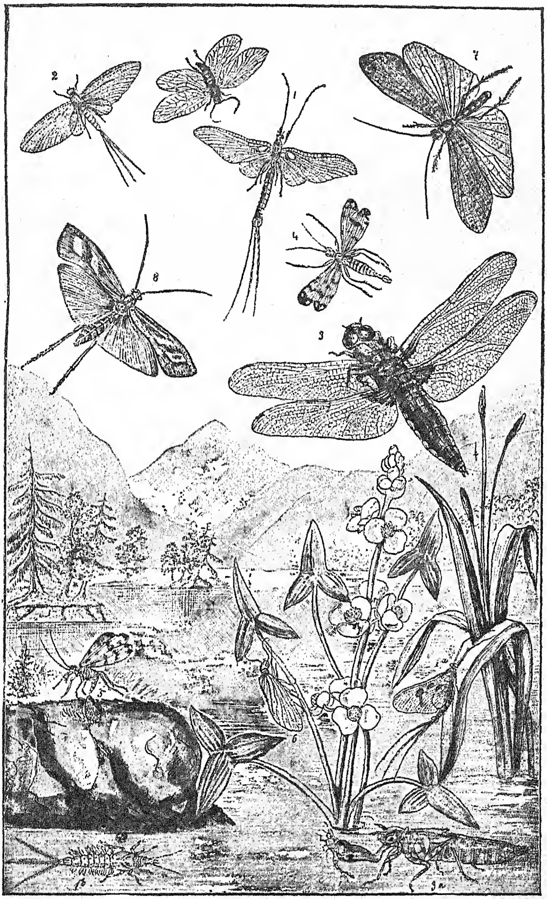


Fig. 228.—Net-winged Insects (*Neuroptera*).

1, 1*a*, 1*b*, Stages of common May-Fly (*Ephemera vulgata*); 2, another species of May-Fly (*Palingenia horaria*); 3, 3*a*, adult and larva of Horse-Stinger (*Libellula depressa*); 4, 5, Common Scorpion-Fly (*Panorpa communis*); 6, 6*a*, Alder-Fly (*Sialis lutaria*); 7, Large Caddis-Fly *Phryganea grandis*); 8, Diamond-spotted Caddis-Fly (*Limnophilus rhombicus*).

about equal size, and the long body is handsomely marked and coloured. The freely movable head is provided with very small antennæ, a pair of huge compound eyes, three simple eyes (ocelli), and biting mouth-parts. Dragon-Flies catch other insects on the wing, and their flight is exceedingly rapid, making them the swallows of the insect world. The eggs are laid either in water or attached to water-plants, and from them extremely voracious aquatic larvæ hatch out, which are distinguished by the possession of an extremely long transversely-jointed lower lip. This is usually known as the "mask", because when not in use it is folded up in front of the face, from which position it can be suddenly shot out for the capture of small animals. The action has been compared to that of an old-fashioned carriage-step. The larval condition is maintained for about a year or rather less, during which time a number of moults occur, while towards the end of the period the rudiments of wings make their appearance. There is no motionless pupa stage, but the full-grown larva climbs up the stem of some plant till it is above water, when its skin splits longitudinally along the dorsal surface, and the adult dragon-fly, which has been meanwhile forming within, gradually works its way out. Over forty species of British dragon-flies are known, of which the following may be mentioned:—The Great Dragon-Fly (*Æschna grandis*), a large reddish-brown insect, with lighter markings; the Horse-Stinger (*Libellula depressa*) (fig. 228), with broad abdomen, light brown, with yellow spots in the female and violet in the male; and the little Demoiselle Dragon-Fly (*Agrion puella*), with T-shaped head, and slender abdomen, black in the female and banded with light-blue in the male.

The *May-Flies* or *Day-Flies* are fragile insects in which the hind-wings are much smaller than the others, and the abdomen has two or three slender tails attached to it. The adult only lives a short time, though the traditional day may in some cases be extended to a fortnight. The life-history broadly resembles that of the dragon-flies, and the larva of some forms appears to live three years, an unusually long time, contrasting sharply with the brief existence of the imago. Something like 300 species have been described, and common British forms are the Common May-Fly or Gray Drake (*Ephemera vulgata*) (fig. 228) and the Green Drake (*E. Danica*). Some of the most successful lures of

the fly-fisher are copies of various may-flies, of which the two drakes are examples, as are also many of the "duns" and "spinners".

Stone-Flies are dull-coloured flattened insects with four membranous wings which, when at rest, are disposed so as to overlap the back and sides of the body. The antennæ are long, and there are usually two filaments of similar appearance attached to the tip of the abdomen. The life-history resembles that of the preceding two groups. Stone-Flies are widely distributed, and include a large number of species. The best-known British form is the Common Stone-Fly (*Perla bicaudata*), well known to anglers as a good bait for trout.

2. *Flat-winged Neuroptera* include Alder-Flies, Snake-Flies, Scorpion-Flies, Ant-lions, Lace-wing Flies, and other forms, in all of which there are four similar wings, not capable of being folded, but turned back when at rest so as to lie either flat, or sloping like the roof of a house. The adult possesses well-developed mandibles, contrasting in this respect with the last group of Neuroptera, in which the mouth-parts are much reduced. There is a terrestrial or aquatic larva, which becomes a quiescent pupa.

The Alder-Fly (*Sialis lutaria*) (fig. 228), which figures on the angler's list, is a brown insect with brownish wings, clumsy body, and long antennæ. The wings in repose cover the thorax and abdomen in a roof-like manner. It is common on river-banks in Britain. The cylindrical greyish eggs are deposited in patches on the stems of grasses or rushes near the water, into which the rapacious larvæ that hatch out from them find their way. Later on, they come out of the water and bury themselves in the soil, where they become pupæ.

Snake-Flies, of which there are several British species (*e.g. Raphidia ophiopsis*), are more slenderly built insects, sometimes found in woods. They are distinguished by the presence of a sort of neck, and there is an ovipositor in the female. The rapacious larva is found in rotten wood, where it passes into a pupa stage.

Scorpion-Flies are much more abundant in this country than Snake-Flies, and the Common Scorpion-Fly (*Panorpa communis*) (fig. 228) may be taken as a type. The name is due to the fact that the abdomen in the male ends in a pair of pincers, and its

hinder part can be curled up over the back like a scorpion's tail. The wings are narrow, and when at rest are held in a horizontal position. The head is of characteristic shape, for it is prolonged into a downwardly-directed beak, which has been compared in appearance to the face of a horse. Though the insect is small (about ½ inch long), its black body, yellow legs and beak, and wings speckled with white and brown make it a striking and beautiful object. The larva is predatory and terrestrial, being not unlike the false caterpillar of a saw-fly in appearance, possessing as it does three pairs of legs proper, followed by eight pairs of pro-legs. Later on, it passes into a quiescent pupa stage.

Ant-Lions are insects with slender body, four equal membranous wings, and antennæ clubbed like those of butterflies. They do not occur in this country, but are common on the Continent, where they have long attracted attention from the peculiar habits of the larvæ in the type-genus (*Myrmeleo*). It is these to which the name ant-lion was originally applied on account of the devastations they commit among those and other insects, their mode of operation being to dig pit-falls in the sand, at the bottom of which they remain buried, with only the enormous mandibles projecting.

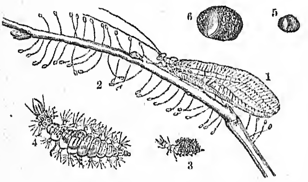


Fig. 229.—Golden-eyed Fly (*Chrysopa vulgaris*)
1. Adult female; 2, stalked eggs; 3, 4, larva (natural size and enlarged); 5, 6, cocoon (natural size and enlarged).

Lacewing-Flies are represented by about fifteen native species, a common example being the Golden-eyed Fly (*Chrysopa vulgaris*) (fig. 229), an extremely fragile green insect with four gauzy wings, long slender antennæ, and brilliant eyes gleaming like gold. The eggs are attached to leaves by long stalks, and the voracious larvæ which hatch out from them are known as "aphis lions", a name fully justified by the effective manner in which they keep plant-lice in check.

3. *Caddis-Flies* (fig. 228) in the adult condition look rather like moths, but their wings are hairy instead of scaly, and their larvæ are aquatic "caddis-worms", remarkable for the habit of forming protective cases from sand-grains, bits of stick, or other foreign matters. A caddis-worm is something like a caterpillar,

devoid, however, of pro-legs, while at the end of its tail is a pair of pincers by which it can attach itself firmly to the case. The food is mainly of vegetable nature. After from seven to ten months the larva closes the opening of the tube with silk and passes into the pupa stage, which, after remaining quiescent for two or three weeks, bites its way out of the case and swims on its back to some plant or other object up which it can climb out of the water. The pupal skin then splits, and the caddis-fly emerges.

4. *White Ants*, more correctly called *Termites*, since they have nothing whatever to do with ants proper, are but too well known to the inhabitants of tropical countries on account of the havoc they work with wooden furniture and the like. They are social insects, living in communities organized in an extraordinarily complex manner, about which particulars will be given in the sequel. In every community both winged and wingless individuals may be found, the former possessing four very long narrow wings of the kind characteristic of the order, which are held flat on the back when at rest. There is but a slight metamorphosis. Two species are found in South Europe (*Calotermes flavicollis* and *Termes lucifugus*), but the most remarkable forms are natives of tropical Africa, and some of these (*e.g.* *Termes bellicosus*) construct nests of earth which may be as much as 14 feet high.

Book-Lice are minute forms of somewhat doubtful affinities, and most familiarly known by the wingless species giving the name to the group, but also including the "death watches" (*Atropos divinatoria* and others), commonly reputed by the superstitious to herald death by a ticking noise, though the sound is more probably produced by a wood-eating beetle (*Anobium*). The winged species, which are the most numerous, are to be found feeding on lichens, fungi, and other plants. Of the four membranous wings, which are provided with but few nervures, the hind ones are much the smaller. The antennæ are very long. There is but a slight metamorphosis. Among the British winged species may be mentioned *Psocus fasciatus*.

5. *Biting-Lice* are small wingless, large-headed creatures which live on the skins of birds and mammals, and must carefully be distinguished from ordinary lice (p. 354), in which the mouth-parts are adapted for piercing and sucking. The common

fowl is infested by no less than five species (*Menopon pallidum* and others), and the "dust baths" in which this bird indulges are no doubt taken with a view of getting rid of these and other parasites. Mammals are less troubled with attacks of the kind, the dog being an example of animals which are thus attended. *Trichodectes latus* is the name of its unwelcome guest.

Order 8.—Straight-winged Insects (Orthoptera)

The Cockroach, of which an account has already been given, may be taken as a type of this order, which also includes such familiar forms as locusts, grasshoppers, earwigs, and crickets. The *mouth-parts* are adapted for biting, and it is particularly to be noticed that the second maxillæ are not so closely fused together to form a lower lip or labium as in most other insects. The *fore-wings* are modified into leathery wing-covers, and the large membranous hind ones are usually traversed by nervures radiating from the point of attachment, and are thus enabled to fold up in a fan-like manner when not in use. There can scarcely be said to be a metamorphosis, for the young insects when just hatched differ from the adult mainly in size and in the absence of wings, while there is no quiescent pupa stage. It is supposed that at least 10,000 species of recent Orthoptera exist, including the largest known insects, but of this large number less than forty are native to Britain. A distinction is drawn between: 1. Running Orthoptera, including Earwigs, Cockroaches, Soothsayers, Stick-Insects, and Leaf-Insects; 2. Leaping Orthoptera, embracing Grasshoppers, Locusts, and Crickets.

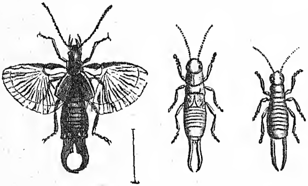


Fig. 230.—Common Earwig (*Forficula auricularia*) Adult (line indicates actual size) and earlier stages

1. In *Running Orthoptera* all three pairs of legs are pretty much alike. The Common Earwig (*Forficula auricularia*) (fig. 230) may be taken as a type of a family in which the wings are folded up in a remarkably complex manner under the short wing-covers, and the tail is provided with curved forceps. No satisfactory explanation has been given of the curious

popular notion that these insects are in the habit of entering the human ear, for this does not appear to be the case, and though it is true that the hind-wings are strikingly ear-shaped, they are so rarely seen unfolded that it may be doubted whether this has to do with the name "earwig".

Cockroaches are widely distributed insects, especially common in tropical regions. Only three small species appear to be indigenous to Britain, for the familiar "black beetle" is undoubtedly an importation. Some of the exotic species are brightly coloured, while others are wingless.

Soothsayers or *Praying-Insects* form a remarkable group dependent upon a warm climate, and often assuming the most extraordinary forms, calculated in many cases to harmonize with the surroundings, being thus rendered inconspicuous to their prey, which consists of other insects. The front-legs are modified into seizing-organs, and it is the curious way in which these are extended that has given rise to the common names, as, *e.g.*, that of Praying Mantis (*Mantis religiosa*) applied to a French species, the only European one found at any great distance from the Mediterranean shores. A Mantis in such an attitude is, however, merely on the look-out for insects, and not in a prophetic or devout frame of mind.

Stick- and *Leaf-Insects* assume even more remarkable forms than the members of the preceding family, and mostly have a close resemblance to sticks, leaves, pieces of bark, and other parts of plants, which in this case may be looked upon as a protective arrangement, for, unlike the Soothsayers, they affect a vegetable diet. They are widely distributed through the warmer parts of the globe, and some of them may be as much as 9 inches long.

2. *Leaping Orthoptera*, in accordance with their habit of springing, possess very large hind-legs. Remarkable structures related to hearing are usually present, and the males generally possess musical organs as well. Three families are recognized—Locusts and Grasshoppers, Green Grasshoppers, and Crickets.

Locusts and *Grasshoppers* are distinguished by the shortness of their antennæ and the presence of auditory organs in the first segment of the abdomen. The familiar little grasshoppers of British fields represent a number of species of varying size, some of the larger belonging to the genera *Stenobothrus* and *Gomphocerus*,

while the very smallest are included in the genus *Tettix.* The characteristic chirping is produced by rubbing the inner side of the hind-legs against the outer surface of the front wings, the former being provided with a ridge made up of small peg-like projections. The sounds audible to human ears are produced only by the male.

What are popularly known as "locusts" are simply species of grasshopper, which from time to time appear in swarms

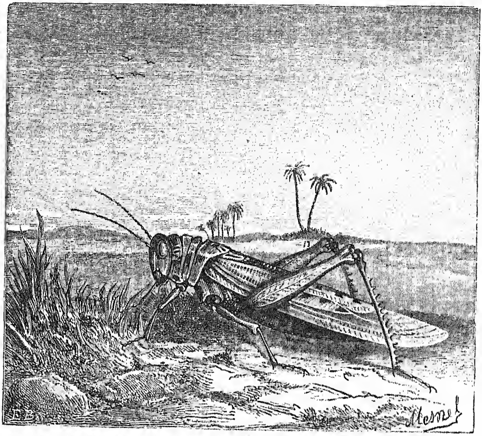


Fig. 231.—Migratory Grasshopper—"Locust" (*Acridium peregrinum*)

which migrate from place to place and do a vast amount of damage. The best-known species is the European migratory locust, which ranges from China to the Atlantic. A large species (*Acridium peregrinum*) (fig. 231), common in North Africa, is probably the locust mentioned in the book of Exodus.

Green Grasshoppers are easily distinguished from the members of the preceding group by their extremely long and slender antennæ. There are generally auditory organs situated in the front legs just below the knee. Chirping organs, when present, are placed on the bases of the fore-wings, the left carrying a roughened edge (file) and the latter a sharp edge. In most species the female possesses a long egg-laying tube or ovipositor.

The most conspicuous British species is the Large Green Grasshopper (*Locusta viridissima*) which, despite its generic name, is not a locust at all. Other examples are the North American Katydids.

Crickets agree in many essential particulars with the members of the preceding group, possessing as they do long, slender antennæ and similarly situated musical and vocal organs, while the female is usually provided with an ovipositor. There are, however, differences in detail; *e.g.* the tarsus is usually three-jointed instead of four-jointed, and the musical organs involve a larger part of the wing. There are four different kinds of cricket in the British area, of which by far the most familiar is the House-Cricket (*Gryllus domesticus*), which is one of the animals most constantly associated with human dwellings, and is not unconnected with superstitious ideas. Habit has rendered its chirpings agreeable to our ears, and Dickens's ever-popular story, *The Cricket on the Hearth*, gives it an interest which few Orthoptera can boast. It is perhaps rather unromantic to add that in dramatic presentments of the tale the all-important chirp is imitated by using a glass-stoppered bottle, the stopper of which is twisted round so as to produce a creaking sound. This particular insect ranges over a large part of the Old World, and also occurs in North America. Its distribution has probably been extended by human agency. Of the two British species of Field-Cricket, one (*Nemobius sylvestris*) is small in size, while the other (*Gryllus campestris*) is a good deal larger than the Common Cricket, and usually black in colour. The Mole-Cricket (*Gryllotalpa vulgaris*) (fig. 232) is a remarkable form, practically limited to the south of England with us, though common on the Continent. It burrows underground by means of its remarkably modified fore-feet, and its habits will be dealt with elsewhere.

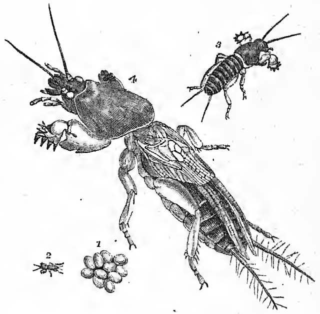


Fig. 232.—Mole-Cricket (*Gryllotalpa vulgaris*)
1, Eggs; 2, 3, larvæ; 4, adult.

Order 9.—Wingless Insects (Aptera)

This is a group of small inconspicuous insects which are of great interest theoretically, as they are probably to be regarded as insects in their simplest form, *i.e.* are of "primitive" nature. They never possess any traces of wings, nor do they appear to be descendants of winged ancestors, as is the case with the numerous wingless insects placed in other groups. The segmentation of the body is more clearly marked than in other insect orders, and the segments are not so specialized, besides which small abdominal appendages are not uncommon. The horny covering of the body is comparatively delicate. Two sub-orders are recognized:— 1. Tassel-Tails (*Thysanura*) and 2. Springers (*Collembola*).

1. *Thysanura.*—The most marked feature of the sub-order consists in the presence of two or three long styles projecting from the hind end of the body. Probably the commonest British species is the Silver-Fish (*Lepisma saccharina*) (fig. 233), found in brown sugar and old books. It possesses three tail-filaments, and its silvery lustre is due to the presence of peculiar scales, which make beautiful microscopic objects. Another species, common in the crevices of rocks at the sea-side, is *Machilis maritima*, which is not unlike the preceding, but grey in colour instead of silvery.

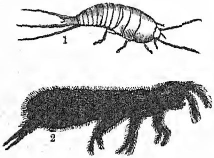


Fig. 233.—Aptera (magnified)
1, Silver-Fish (*Lepisma saccharina*); 2, Glacier-"Flea" (*Desoria glacilis*).

2. *Collembola.*—Many, but by no means all, of these possess a curious springing apparatus in the form of two stiff bristles which can be folded under the body and secured by a sort of catch projecting from the third segment. When released the animal is thrown into the air much like the "jack-jumper" children are so fond of fabricating from the "merrythought" of a goose. They are common under bark, dead leaves, stones, &c., and one species (*Podura aquatica*) may often be seen floating on the surface of stagnant pools. Some kinds are abundant in Alpine regions, on the surface of snow or ice, and among these may be mentioned the Glacier-"Flea" (*Desoria glacialis*) (fig. 233). The Collembola are not all provided with a springing

apparatus, and of these special interest attaches to *Anurida maritima*, remarkable for its habit of floating on the surface of rock-pools along certain parts of the coast. As remarked elsewhere, insects as a rule are very intolerant of salt water.

Class 2.—SPIDER-LIKE ANIMALS (Arachnida)

This class is constituted by Scorpions, Spiders, Mites, and other allied forms, though the affinities of some of these is more than doubtful. The majority of species live upon animal matter, and many of them pursue living prey. Arachnids are popularly confused with insects, from which, however, they differ in many

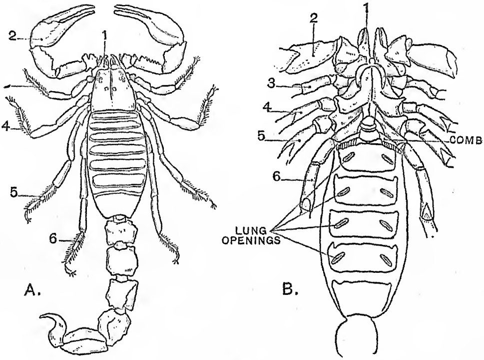


Fig. 234.—Scorpion, seen from above (A) and below (B). 1, Chelicerae; 2, pedipalps; 3-6, walking legs.

important particulars. These differences, as well as the points of agreement, will be best understood by briefly describing a Scorpion as a type (fig. 234). Spiders are more familiar to us in this country, but as they are much specialized it will be better to take them later. In dealing with the Scorpion, comparison may well be made with the account of a typical insect given on pp. 343–350.

The obviously segmented body is protected by a firm horny coating, which is very thick and hard in some places, while in others it is comparatively soft and flexible, so as to permit of a certain amount of movement. The body is not divided, as in

an insect, into well-defined head, thorax, and abdomen, for the parts commonly considered as equivalent to the first two of these are fused together into one mass known as the *cephalo-thorax*, which consists of at least six segments, for it bears six pairs of appendages. The remainder of the body is made up of twelve rings or segments, the last five forming a narrow *tail* which is carried bent up over the body, and bears at its tip a pear-shaped spine on the sharp end of which open two poison-glands. Here we have an example of a true "sting", like that of a bee or wasp, as contrasted with the biting arrangements found in serpents, bugs, and gnats.

The *appendages* of a Scorpion differ strikingly from those of an insect. Instead of antennæ, three pairs of jaws, and three pairs of walking-legs, we find two pairs of grasping organs and four pairs of walking-legs, while feelers or antennæ are not present as such. The first pair of these appendages are short, strong, forwardly-directed *nippers* (cheliceræ), and they are followed by a very large second pair (pedipalps), which end in strong *pincers* much like those of a lobster and used for seizing prey. The bases of these appendages are adapted for biting. The possession of eight *walking-legs* is as characteristic of an Arachnid as that of six is of an insect, and this affords the simplest means of distinguishing the members of the two classes.

The two segments which immediately succeed the cephalo-thorax also bear structures which are interpreted as appendages, the first being fused into a small plate (operculum) notched behind, while the others are comb-shaped organs (pectines) which probably have a tactile function.

An ordinary insect breathes by means of air-tubes which open to the exterior by a series of pores on each side of the body, but the respiratory organs of a Scorpion consist of four pairs of "lung-books" which open by a corresponding number of oblique slits placed on the under side of the segments following the one upon which the comb-shaped organs are borne. Each of these breathing organs consists of a cavity into which a large number of thin plates project, these being packed together in a way which suggests the leaves of a book, hence the name lung-"book". An insect, again, typically possesses a pair of large compound eyes, and simple eyes may be present in addition. Here the eyes are all simple and are arranged on the upper side

of the cephalo-thorax, two of them being close together near the middle line, while the remainder form a couple of groups, one on each side, near the front end of the body. Each of these groups contains from two to five separate eyes. The development takes place without metamorphosis.

The class is divided into the following orders:—

1. Scorpions (SCORPIONIDÆ).
2. False Spiders (SOLPUGIDÆ).
3. False Scorpions (PSEUDOSCORPIONIDÆ).
4. Whip-Scorpions (PEDIPALPI).
5. Harvestmen (PHALANGIDÆ).
6. Spiders (ARANEIDÆ).
7. Mites (ACARINA).

To these are usually added two small groups of doubtful affinities, *i.e.*—

8. Tongue-Worms (LINGUATULIDÆ).
9. Bear-Animalcules (TARDIGRADA).

Order 1.—SCORPIONS (Scorpionidæ)

Scorpions, all of which conform to the description already given, are widely distributed throughout the warmer parts of the globe. Two common South European species are the little House-Scorpion (*Euscorpius Europæus*), which ranges as far as the Tyrol and Carpathians; and the much larger Field-Scorpion (*Buthus Europæus*), common in the Mediterranean countries. The largest and most poisonous forms are the black *Rock-Scorpions* of Africa and India, which may be as much as 9 inches in length. These belong to the type-genus *Scorpio*.

Order 2.—FALSE SPIDERS (Solpugidæ)

The order of False Spiders includes a small number of species having a wide distribution, and mostly limited to warm countries. A well-known type is the Common False-Spider (*Galeodes araneoides*) (fig. 235), found in South Russia, Persia, Arabia, and Egypt, and much feared on account of its poisonous bite. The Kalmucks, Kirghiz, and other nomad tribes avoid regions where it abounds, for its attacks are not limited to human

beings, but extend also to domestic animals, such as sheep, and camels. This creature resembles a large spider in appearance: its body is about 2 inches long and its legs long and hairy. There are great differences of structure and proportion as compared with a Scorpion. The body is unique among Arachnids in being distinctly divided into *head*, *thorax*, and *abdomen*, much as in an insect, and the last region is composed of ten segments and cylindrical in shape, there being no sting-provided tail. A further resemblance to insects is found in the breathing organs, which consist of *air-tubes*, opening to the exterior by three pairs of stigmata situated on the under surface, the first at the bases of the second legs, and the others on the abdomen. As in a Scorpion, the first appendages are *nippers*, here of very large size, and constituting the chief offensive weapons, since poison glands open upon them. The *pedipalps*, however, are not, as in a Scorpion, stout and pincer-bearing, but slender leg-shaped structures having a forward direction and acting as tactile organs. The first pair of legs closely resemble the pedipalps in appearance and function, and it may be noted that these four similar appendages are provided at their bases with cutting projections, situated at the sides of the mouth and serving as jaws. The remaining legs are attached to the thorax, as in an insect, the resemblance being emphasized by the fact that each ends in a claw-bearing tarsus. There is nothing to correspond to either the operculum or the combs of a Scorpion, and only two *simple eyes* are present, placed on the front of the head close to the middle line.

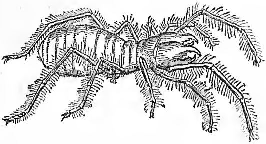


Fig. 235.—Common False-Spider (*Galeodes araneoides*)

Order 3.—False Scorpions (Pseudoscorpionidæ)

False Scorpions are minute widely-distributed animals not unlike Scorpions in appearance, the resemblance being due to similarity in the appearance and structure of the chelicerae, pedipalps, and walking-legs. There are, however, no poison-glands, and the broad flat abdomen does not narrow into a tail. Breathing is effected by means of *air-tubes*, which open on the under side

of the abdomen by two pairs of stigmata. *Spinning glands* open on the cheliceræ, and the *simple eyes*, two or four in number, are situated on either side of the front of the head.

A common European species is the little Book-Scorpion (*Chelifer cancroides*) (fig. 236), often found in old books and similar dark places.

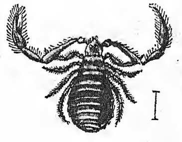


Fig. 236.—Book-Scorpion (*Chelifer cancroides*), enlarged. Natural size indicated by line.

Order 4.—Whip-Scorpions (Pedipalpi)

The Whip-Scorpions make up a small but widely-distributed order, the members of which are fairly large in size. They are found in the warmer parts of both hemispheres, and considerable interest attaches to them, owing to the fact that they are in some respects intermediate between Scorpions and Spiders, on which account they are sometimes called Scorpion-Spiders. A typical Whip-Scorpion (*Thelyphonus*) looks not unlike a real Scorpion, the pedipalps being large and provided with pincers, and the abdomen narrowed into a sort of tail, reduced, however, to a mere filament. The breathing organs are lung-books (two pairs), and the eyes are arranged in a central and two lateral groups. Among the important differences from Scorpions may be noted—cheliceræ provided with claws, not nippers, modification of the first pair of legs into tactile organs, and distinct marking off of the abdomen.

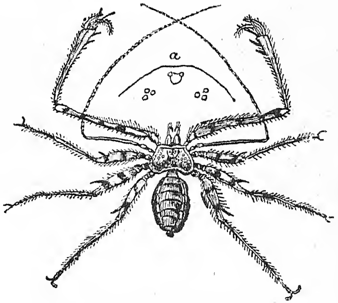


Fig. 237.—A Whip-Scorpion (*Phrynus*). *a*, Front of cephalo-thorax, enlarged to show eyes.

Some of the other genera (as *Phrynus*) (fig. 237) approximate more closely to the Spiders, for the pedipalps possess claws instead of pincers, and the abdomen is joined to the rest of the body by a narrow waist. The tail filament is only represented by a button-like knob.

Order 5.—HARVESTMEN (Phalangidæ)

Harvestmen constitute a large and almost universally-distributed order, represented in this country by some two dozen species. They are common in our fields and are generally mistaken for spiders, from which, however, the native species can at once be distinguished by the great length and slenderness of the four pairs of legs, and the fact that the small oval body is not marked off distinctly into regions. The cheliceræ are provided with relatively large pincers, but the pedipalps are usually short and leg-like. The breathing organs are air-tubes which open by a pair of stigmata on a forward prolongation of the abdomen, just behind the bases of the first legs. A pair of simple eyes is borne on the upper surface of the cephalo-thorax. *Phalangium opilio* is one of the commonest native species (fig. 238).

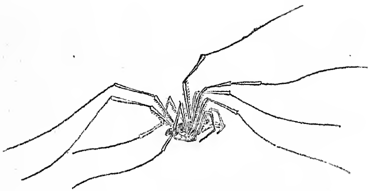


Fig. 238.—A Harvestman (*Phalangium opilio*)

Order 6.—SPIDERS (Araneidæ)

Spiders make up a very large and widely-distributed order, of which there are several thousand known species. A well-known British form is the large Garden-Spider (*Epeira diadema*) (fig. 239), which constructs large regular webs resembling a wheel in shape. The ground-colour varies from yellowish to dark brown, diversified by darker markings, and usually presenting a conspicuous white mark on the upper side of the abdomen, whence the German name of "cross-spider" (*Kreuzspinner*), and the French name "cross-carrier" (*porte croix*). As in a scorpion, the head and thorax are closely fused together, but the large egg-shaped abdomen is connected by a narrow wasp-waist to the rest of the body, and the segments of which it is made up are so intimately united together that the boundaries between them cannot be made out.

The first pair of appendages (*chelicerœ*) are two-jointed, and

of very characteristic construction, for the sharp curved end-joint, at the tip of which a pair of poison-glands open, can be folded down on the basal joint, much as the blade of a pocket-knife folds down on the handle. In this way an efficient grasping and holding organ is formed. The *pedipalps* are slender forwardly-directed structures, looking something like antennæ. As in

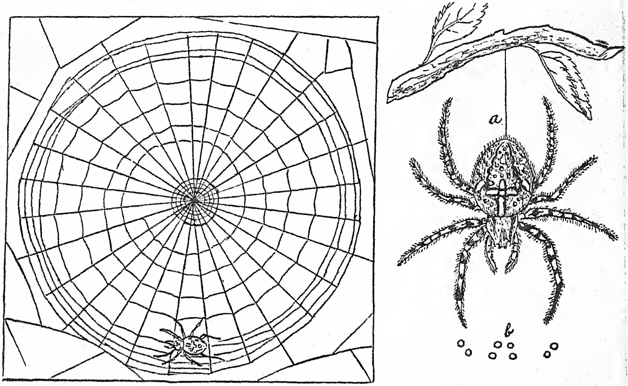


Fig. 239.—Garden-Spider (*Epeira diadema*) and Web. *a*, Female spider; *b*, arrangement of eyes.

Scorpion their basal joints are provided with cutting edges, which work against one another and act as jaws. The tips of the pedipalps are curiously modified in the male. The four pairs of *legs* are strong and of considerable length. Each of them is provided at its tip with several toothed claws, serving as efficient grasping organs.

As regards *breathing organs*, the Garden-Spider combines the arrangements characteristic of Scorpions on the one hand and Insects on the other. There are two lung-books, which open by a pair of slits on the under-side of the abdomen, near its base, while farther back there is a single aperture, situated in the middle, and opening into a set of air-tubes.

One of the most striking peculiarities of an ordinary spider is its power of spinning webs: indeed the word spider probably means "spinner". The silk is made by a large number of spinning-glands situated in the hinder part of the body, and

opening upon conical "spinnerets", of which there are six in the Garden-Spider, four large and two small. They will be found as conical projections on the under side of the abdomen near its tip.

The Garden-Spider possesses eight *simple eyes*, situated on the upper side of the cephalo-thorax, at its front end. Four of them are comparatively large and are placed at the corners of a square, on each side of which are a pair of rather smaller ones. As in Arachnids generally the young resemble the adult when hatched, except in size.

There are two sub-orders: 1. Segmented Spiders, and 2. Unsegmented Spiders.

1. *Segmented Spiders* are represented by certain large East Indian species, characterized by well-marked segmentation of the abdomen and the possession of two pairs of lung-books, agreeing in these respects with the whip-scorpions. A further peculiarity is the presence of eight spinnerets, grouped together on the under-side of the abdomen, and placed much farther forwards than in an ordinary spider.

2. *Unsegmented Spiders* include all the common forms, of which Epeira has been taken as a type. The sub-order is again divided into two groups according to the number of lung-books present, *i.e.* into Four-lunged Spiders and Two-lunged Spiders.

Four-lunged Spiders include the largest members of the order, which excavate burrows in the ground and line them with silk, but do not construct snaring-webs. Some of these prey upon small birds, *e.g.* the Bird-eating Spider (*Mygale avicularia*), a gigantic South American form often seen in collections. Here also are included the *Trap-door Spiders* (*Cteniza* and *Nemesia*) of South Europe and elsewhere, which make hinged lids to their burrows. There is only one British species (*Atypus Sulzeri*), which burrows in damp earth.

Two-lunged Spiders, of which *Epeira diadema* is a typical example, embrace the large majority of species, and all the British forms except Atypus. Only some of the kinds construct snaring-webs, and among these may be mentioned, in addition to the Garden-Spider, the common House-Spiders (*Tegenaria domestica* and *T. civilis*), and the Hedge-Spider (*Agalena labyrinthica*), which constructs strong horizontal webs on bushes, hedges, &c. A very interesting aquatic form is the Water-Spider (*Argyroneta*

aquatica), which constructs a thimble-shaped nest under water, attaching it to surrounding objects by mooring-strands which also serve to snare prey. The nest is filled with air, which the spider brings down in the form of bubbles adhering to its hairy abdomen.

Examples of common British spiders which do not construct webs are the Wolf-Spiders (*Lycosidæ*), and the handsomely-stripèd Harlequin-Spider (*Salticus scenicus*), distinguished by its leaping powers.

Order 7.—MITES (Acarina)

Mites, as their name indicates, are minute forms, and they embrace an exceedingly large number of species, some of which are found almost everywhere. A typical example is the Cheese-Mite (*Tyroglyphus siro*) (fig. 240). The abdomen is unsegmented and closely fused with the cephalo-thorax, the entire body being oval in shape. The small cheliceræ are provided with pincers, and the pedipalps are short and slender.

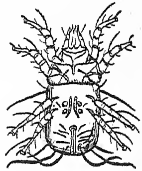


Fig. 240.—Cheese-Mite (*Tyroglyphus siro*), seen from below. Enlarged forty times.

The usual four pairs of walking-legs are present, two directed forwards and two backwards. Respiratory organs are absent. Another well-known species is the "Red-Spider" or "Money-Spinner", which lives on the juices of leaves and spins a protective web. One of the chief features in which it differs from the Cheese-Mite is in the possession of breathing organs, which are in the form of air-tubes. Other examples of the group are Ticks, Mange-Mites, and similar pests, which will be dealt with in another section.

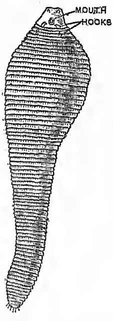


Fig. 241.—Tongue-Worm (*Pentastomum tænioides*)

Order 8.—TONGUE-WORMS (Linguatulidæ)

Tongue-Worms are worm-like forms which in the adult condition are found as parasites in the nasal cavities of Dog and Wolf. The only appendages are two pairs of hook-like structures in the neighbourhood of the mouth. *Pentastomum tænioides* is the type (fig. 241).

Order 9.—Bear-Animalcules (Tardigrada)

Bear-Animalcules are minute creatures found in damp moss, or sometimes in salt or fresh water. The shape of the body ludicrously suggests an unlicked bear-cub (fig. 242). There are four pairs of stump-like legs, each provided with a pair of claws at its tip. The only representatives of jaws are to be found in a pair of sharp stylets which can be protruded from the mouth.

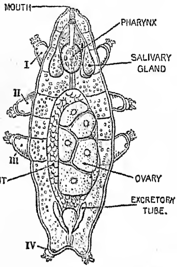


Fig. 242.—A Bear-Animalcule (*Macrobiotus*), much enlarged and seen from above; I–IV, walking legs.

Class 3.—Centipedes and Millipedes (Myriapoda)

Centipedes and Millipedes, which make up the third class of Jointed-limbed Invertebrates, are of simpler structure than the average members of the preceding classes, Insecta and Arachnida, contrasting strongly with them in regard to the legs, of which numerous similar pairs are present, though by no means so many as the names "centipede" and "millipede" would seem to imply. A common British centipede, the Thirty-Foot (*Lithobius forficatus*) (fig. 243), may be taken as a type. This is a small chestnut-coloured creature which lurks under stones or among loose earth, and glides rapidly away when disturbed. The body is flattened from above downwards, and is made up of a head and trunk, the latter consisting of sixteen segments, of which the first is extremely narrow, while each of the remainder bears a pair of jointed legs ending in pointed claws. The last two legs are much larger than the others, and turn sharply backwards. The narrow first segment of the trunk is provided with a pair of modified limbs, the bases of which are fused together, while each of them ends in a strong curved claw, near the end of which a poison gland opens.

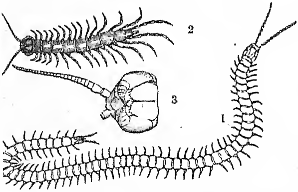


Fig. 243.—British Centipedes: 1, (*Geophilus longicornis*); 2, the Thirty-Foot (*Lithobius forficatus*); 3 is under side of head enlarged.

The most obvious appendages of the head (fig. 244) are two long-jointed antennæ, while the remainder consist of three pairs of *jaws* guarding the opening of the mouth, and overlapped by the poison-claws. There is also a plate-like upper lip. The jaws, which are comparable in some respects to those of a cockroach (see p. 345), consist of a pair of hard-biting *mandibles*, followed by delicate flattened *1st maxillæ*, and these again by leg-like *2nd maxillæ*.

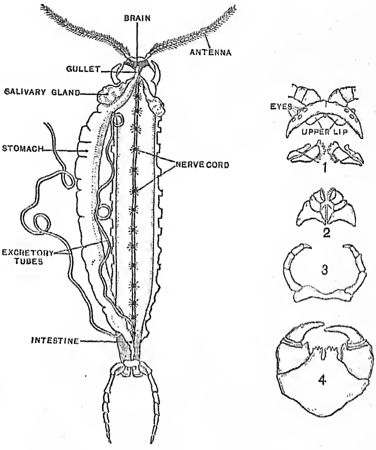


Fig. 244.—Structure of Centipede

1, Mandibles; 2, first maxillæ; 3, second maxillæ; 4, first limbs of trunk, with poison claws

As in an insect, the breathing organs are *air-tubes* ramifying throughout the body, opening to the exterior on the sides by small holes (stigmata), of which the 3rd, 5th, 8th, 10th, 12th, and 14th leg-bearing segments each bears a pair. A group of *simple eyes* is to be seen on each side of the top of the head.

It will be seen from the above description that a Myriapod is decidedly simpler in structure than an Insect or average Arachnid, only the front part being clearly marked off as a head, while there is no distinction between thorax and abdomen, though the first segment of the trunk is specialized. The presence of numerous pairs of legs, extending right to the posterior end of the body, is also characteristic, there being no restriction of walking-legs to the front part of the trunk, as in a scorpion or cockroach, where there are no legs on the abdominal region. As in many other cases of animals with unspecialized trunk, there is considerable variation within the limits of the class as to the number of segments, and another noteworthy point is the similarity these segments exhibit among one another.

Myriapods are divided into the following five orders:—

1. Millipedes (CHILOGNATHA or DIPLOPODA).
2. Centipedes (SYNGNATHA or CHILOPODA).
3. Spider-legged Myriapods (SCHIZOTARSIA).
4. Insect-like Myriapods (SYMPHYLA).
5. Larva-like Myriapods (PAUROPODA).

Order 1.—MILLIPEDES (Chilognatha or Diplopoda)

Millipedes (fig. 245) are vegetarian Myriapods, devoid of poison-claws, and with cylindrical bodies. The legs are comparatively weak, and throughout the greater part of the trunk two pairs of them are borne by each segment, their bases being close together instead of wide apart, as in a Centipede. The antennæ are short and club-shaped, while each of them is made up of seven somewhat bell-shaped joints. The mouth is provided with a plate-shaped upper lip, strong mandibles, and two pairs of maxillæ fused together into a broad plate. There are two pairs of stigmata on each trunk-segment, and also two small pores (*foramina repugnatoria*), which are the openings of defensive stink-glands. The eyes resemble those of a Centipede in structure and position.

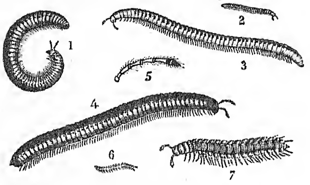


Fig. 245.—British Millipedes

1, London Snake-Millipede (*Iulus Londinensis*); 2, 3, Spotted Snake-Millipede (*Iulus guttatus*), natural size and enlarged; 4, 5, Earth Snake-Millipede (*Iulus terrestris*) and antennæ of same, both enlarged; 6, 7, Flattened Millipede (*Polydesmus complanatus*), natural size and enlarged.

Millipedes differ very much in length. A common British species of average length is the Earth Snake-Millipede (*Iulus terrestris*), a sluggish creature about an inch in length, commonly found under loose bark, &c., and with the habit of curling itself up when alarmed. The *Pill-Millipedes* are short forms which roll themselves into compact balls under similar circumstances. The genus *Glomeris* is represented by British species.

Order 2.—CENTIPEDES (Syngnatha or Chilopoda)

Centipedes conform in the main to the description already given of the common British form (*Lithobius*). The large Centi-

pedes of tropical countries, feared on account of their painful bite, constitute a widely-distributed family, including larger and longer forms, provided with twenty-one pairs of legs. Some of them may be as much as a foot in length. A well-known species is *Scolopendra morsitans.* Another family of Centipedes, found all over the world except in the coldest regions, includes slender elongated forms, which are devoid of eyes, and burrow underground in pursuit of earth-worms. Some of them are phosphorescent (fig. 243), as, *e.g.*, the common British species (*Geophilus longicornis*).

Order 3.—Spider-legged Myriapods (Schizotarsia)

Spider-legged Myriapods include the species of a genus (*Scutigera*) which is widely distributed through the warmer parts of the globe. The body is comparatively short, but antennæ and legs are very much elongated. The eyes are compound, a unique peculiarity in the class. The breathing organs differ considerably from those of ordinary Myriapods, and open to the exterior by a single row of stigmata placed in the middle line on the upper side of the trunk. They are very active creatures, and most of them pursue their prey in broad daylight, even when the sun is strong.

Order 4.—Insect-like Myriapods (Symphyla)

Insect-like Myriapods include but one genus (*Scolopendrella*), of very small size, and represented by a number of widely-distributed species, of which two are British. The adjective "insect-like" is used on account of the very strong resemblance which exists to the primitive insects of the order Thysanura (p. 384), and some zoologists go so far as to state that we should look upon these forms as coming very near to the ancestral stock from which insects have been derived. There is at any rate a close relationship.

Order 5.—Larva-like Myriapods (Pauropoda)

The order of Larva-like Myriapods includes certain exceedingly small creatures first discovered in Britain, and thought at first by their discoverer (Sir John Lubbock) to be larvæ.

The most remarkable character is found in the antennæ, which are branched. No breathing organs have, so far, been discovered. The type-genus is *Pauropus.*

CLASS 4.—PRIMITIVE TRACHEATES (PROTOTRACHEATA)

There are certain small groups of animals to which special interest attaches on account of the speculations regarding genealogy and origin of organs to which they have given rise. One such group is the Hemichorda, already briefly described (p. 300); another is the class now to be dealt with. It includes but a single genus, *Peripatus*, a primitive type which appears to be of great antiquity, and as the name of the class indicates, is supposed to represent the ancestral stock from which the air-breathing arthropods already described have been derived. The word "represent" must, however, as in such cases generally, be taken with some qualification, for Peripatus can only be regarded as representing that stock in a general sort of way, as no doubt it has to some extent specialized on lines of its own, acquiring peculiarities which adapt it to a special mode of life. To those who are not professed zoologists it may appear that specialists make an unnecessary fuss about an obscure creature that may briefly be described as a "permanent caterpillar"; but the marvel is explained when we remember that this lowly animal enables us to throw light upon the origin and relationships of Myriapods, Arachnids, and Insects, the last of which, taken by themselves, include the majority of terrestrial species.

Like many archaic forms, Peripatus has an extremely wide geographical distribution, and its included species are found in South Africa, the Malay Peninsula, East Australia, New Zealand, South America, Central America, and the West Indies. Yet all these widely-separated species resemble one another with sufficient closeness to be placed in the same genus.

Peripatus was first described (in 1826) as a Mollusc, later as a Myriapod and as an Annelid (segmented worm). The late Professor Moseley, in 1874, proved it to be an Arthropod, and our detailed knowledge of its structure and development is mainly due to the investigations of the late Professor F. Maitland Balfour and Mr. Adam Sedgwick. It is now a widely-accepted view that Arthropods have been derived from Annelids, and the special

interest attached to Peripatus centres in the fact that it, to use the words of Sedgwick, "stands absolutely alone as a kind of half-way animal between the Arthropoda and Annelida".

Peripatus (fig. 246) is a small cylindrical animal, found among rotting wood or the like, and comparable in appearance either to a well-nourished caterpillar or a segmented worm. The velvety *skin* is beautifully coloured, the tint varying according to the species. The front part of the body, called by courtesy the *head*, is not sharply marked off from the *trunk*, and this again is not clearly segmented, though its segmentation is indicated by the fact that it bears numerous pairs of stumpy *legs*, the exact number depending upon the species. These legs are hollow, conical projections (much like the appendages of some Annelids), and only exhibit in an imperfect way the jointing that characterizes Arthropods generally. Each of them is provided with a couple of sharp claws at its tip. Upon the under side of the head there is a swollen circular *lip* surrounding a depression within which the *mouth* opens. On each side of the head, outside this lip, is a short cylindrical projection known as *oral papilla*, and equivalent to a pair of modified limbs. Upon the tip of each of these is the opening of a large *slime-gland*, which secretes a sticky substance that can be forcibly ejected either as a defensive measure or else (in the New Zealand species at any rate) as a means of capturing prey. Within the circular lip are a pair of muscular *jaws*, each armed with two claw-like projections used for chewing the food. These jaws, again, are to be looked on as modified limbs, and the presence of such limb-jaws is an Arthropod character, though the limitation to a single pair is a peculiarity of Peripatus. A pair of cylindrical imperfectly-ringed *antennæ* project from the front of the head, and near the base of each of them there is a simple *eye*.

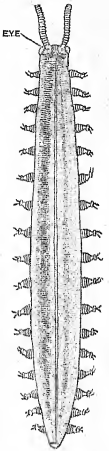


Fig. 246.—Cape Peripatus (*Peripatus Capensis*), enlarged

Only a few of the more important details regarding the *internal structure* (fig. 247) can be mentioned here, and these may be conveniently grouped into: 1. Arthropod characters, and 2. Annelid characters.

1. *Arthropod characters.*—The organs of *circulation* con-

form in the main to the type which has been described for the Cockroach (p. 348). The *heart* is a slender tube placed close to the upper surface of the body and suspended in a blood-containing pericardial space, from which blood passes into it through numerous pairs of valvular apertures. The rest of the blood-system consists of larger and smaller spaces which, together with the heart and pericardial cavity, make up a circulatory arrangement of which the parts communicate with one another.

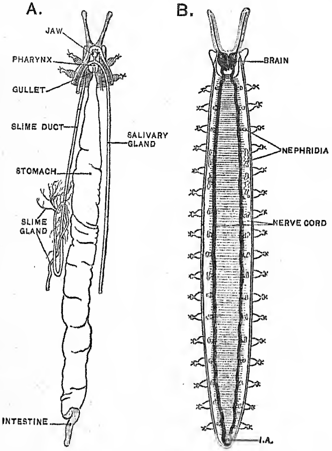


Fig. 247.—Structure of Peripatus

A, Digestive organs (from below). B, Nervous system and excretory organs (from above). I.A. Position of intestinal aperture (on under side).

This appears to be a suitable place in which to speak more fully of the nature of the Arthropod heart, which is essentially a blood-tube within a blood-space with which it communicates by paired apertures. In a Vertebrate (p. 40) or a Mollusc (p. 308) the heart possesses one or more *auricles*, into which blood is poured by veins, and the pericardial space surrounding it does not contain blood at all. Professor Ray Lankester explains the arthropod condition by supposing that the heart was originally a tube receiving blood by several pairs of lateral vessels which later on dilated into auricles where they joined the central tube. The fusion of these auricles into a large space round the heart would give the state of things now existing. The pericardial space of, say, Peripatus is therefore to be regarded, if the theory be well founded, as equivalent to a big auricle surrounding the heart; the physiological problem solved in this case being the evolution of an arrangement for storing blood about to enter the heart.

Peripatus further agrees with typical air-breathing Arthropods

in the character of its *breathing organs*, which are air-tubes. These are, however of very simple character, and open by very numerous stigmata scattered over the surface of the body and even present on the legs. The arrangement is not entirely irregular, for some of these apertures are placed in a double longitudinal row on the upper surface, while others are similarly disposed on the under surface. We have, on the whole, what may be considered a primitive or undifferentiated condition of these organs, from which it is easy to imagine the derivation of the more complex arrangements found in Myriapods, Arachnids, and Insects.

2. *Annelid characters.*—These will naturally be better appreciated after the Annelids have been considered, and will only be briefly enumerated.

The *body-wall*, like that of an ordinary segmented worm, consists of a thin skin covered by a delicate cuticle, and underlain by a muscular coat, consisting of an external layer of transversely-running fibres and an internal layer of fibres having a longitudinal direction. In regard to minute structure, the muscle-fibres differ from those of Arthropods in being devoid of transverse striations.

The mouth of Peripatus leads into a muscular *pharynx*, like that of many Annelids, but quite unlike what is to be found in Arthropods. A much more striking feature is to be found in the *excretory organs*. These consist of a series of tubes known as *nephridia*, one of which opens at the base of almost every leg, on its under surface. Such segmentally-arranged renal organs are extremely characteristic of segmented worms.

The *central nervous system* consists of a double brain- or cerebral-ganglion above the pharynx, and two ventral cords connected with these. A remarkable character is seen in the fact that these cords are widely separated except at the extreme posterior end of the body, where they unite together above the gut. Very numerous slender transverse nerves connect these two cords, much as the rungs of a ladder connect its sides, though the "rungs" of the nervous system differ in being much more narrow and numerous. The nerve cords are dilated at regular intervals into ill-marked ganglia. This nervous system agrees with that of various Annelids, and is also much like that characteristic of the Proto-Molluscs.

Lastly, it may be noted that the eyes of Peripatus agree more closely with those of Annelids than with those of Arthropods.

B.—AQUATIC ARTHROPODS (Branchiata)

The four Arthropod classes which have so far been reviewed, *i.e.* Insects, Arachnids, Myriapods, and Prototracheates, together make up the air-breathing or Tracheate division of Arthropoda; and we now come to the aquatic division, including the two classes of Crustaceans (Crustacea) and King-Crabs (Xiphosura), to which the Sea-Spiders (Pycnogonida) are doubtfully appended.

Class 5.—CRUSTACEANS (Crustacea)

This very large class, of which a typical member, the Lobster, has already been partly described in contrasting Vertebrates with higher Invertebrates (p. 302), includes animals which are for the most part marine, though many, of the minute forms especially, inhabit fresh water, and some few are terrestrial.

So great is the diversity of structure within the limits of the class that no single type fully illustrates it; but it may be as well to enlarge somewhat upon the description already given of the Lobster (*Homarus vulgaris*), taking it as a good average example of the higher Crustacea. To those desirous of seeing how a single type may be made to illustrate the whole of the class in question, and at the same time give a sound knowledge of the principles of zoology generally, a perusal of Huxley's classic work, *The Crayfish*, is recommended.

External Characters of the Lobster (fig. 248).—The body is *bilaterally symmetrical*, and the hinder part of it, or tail, is clearly divided into *segments*. The front part of the body is a *cephalo-thorax*, consisting of head and thorax closely fused together, though segments are present here too, as shown by the numerous paired appendages. The *head* is marked off from the *thorax* by means of a distinct groove (cervical groove). The number of segments appear to be as follows:—head, 5; thorax, 8; tail or abdomen, 7. All the segments, and the appendages they bear, are constructed on the same common plan (see p. 195), but there are many differences in detail, to serve various physiological ends.

Appendages.—The letter Y may be taken as a diagram of the type on which the appendages are constructed, the stem of the letter corresponding to a basal stalk by which the appendage is attached to the body, while its two forks represent outer and inner branches. The same thing may be expressed in another way, by saying that the typical limb in a higher Crustacean is cleft or forked. We will now see how far the appendages of the Lobster conform to this Y diagram, and in doing so it will be convenient to start with the *abdomen*, as this is the least modified region. Of the seven segments here present only the first six bear appendages, while the last, usually known as the *telson*, forms the middle portion of the tail-fin. An average abdominal segment, say the fourth, bears two small forked appendages somewhat inappropriately termed *swimmerets*, and it will be seen from the diagram that these conform to the Y type. The appendages of the sixth abdominal segment are relatively large, and form the side-parts of the great tail-fin. Each of them, however, may be compared to a Y in which the main stem is shortened and broadened, while the two branches are flattened out into oval plates. It may further be noted that the first two pairs of abdominal appendages in the male are curiously modified, while in the female the appendages of the first abdominal segment are either absent or very much reduced.

Thoracic appendages.—The four hindermost segments of the thorax are stout *walking-legs*, of which the two first pairs end in small pincers. At first sight they deviate entirely from the Y type, for they are obviously not forked. This is a case where the facts of development are of use in throwing light on a problem, for we find that in a very young Lobster these walking-legs are forked, but their outer branches are comparatively feeble and ultimately disappear altogether. There is a further peculiarity about the three first pairs of these legs to which attention must be called, but before doing so it is necessary to speak of the nature and position of the breathing organs or *gills*. These are delicate plume-like outgrowths of the body, limited to the thoracic region, and sheltered in a gill-cavity on either side, the outer wall of which is formed by a firm gill-cover that constitutes the side of the *carapace* or hard shield covering the greater part of head and thorax. When

this gill-cover is cut away the gills will be seen, and it can readily be shown that they are of three kinds, attached to different regions of the body. It need only be mentioned here that some of them are *limb-gills*, so called because they are borne by the bases of certain limbs, among which are the three first pairs of legs. When one of these is carefully detached it will be seen that a thin plate (gill-plate) projects from its base, and that to that plate a feathery gill is attached. The fourth thoracic segment bears the most conspicuous appendages of all, *i.e.* the great *pincers*, which are constructed on the same lines as the nipper-bearing walking-legs, and like them are provided with gill-plates and limb-gills.

The three first segments of the thorax bear appendages modified for chewing, and called *foot-jaws*, the name suggesting the idea that they were once locomotor in function but have acquired new duties. The last or third pair of foot-jaws are decidedly leg-like, but are provided with stiff bristles where they bite against one another. An outer branch is present, though small, and gill-plate with limb-gill will be readily recognized. The middle or second foot-jaws are like the preceding, but a good deal smaller, while the first foot-jaws are very delicate, with broad biting basal stalk, small outer and inner branches, and gill-plate devoid of gill.

Head Appendages.—These consist of three pairs of jaws behind and two pairs of feelers in front. The jaws, beginning with the last pair, are named, as in an insect, second maxillæ, first maxillæ, and mandibles. The *second maxillæ* somewhat resemble the first foot-jaws, but gill-plate and gill are absent, while the outer branch is broadened into an oval "baler", which lies in the front of the gill-chamber, and by its constant scooping movement brings about a forward movement of water over the gills. The *first maxillæ* are still more delicate, and are reduced to a two-jointed basal stem and an insignificant inner branch.

The same parts are present in the first jaws or *mandibles*, but their proportions and texture are very different. The basal joint of the stalk is broadened into a hard biting-piece, strongly toothed on its inner margin, while the second joint of the stalk together with the inner branch make up a small three-jointed "palp" which probably has sensory functions.

Owing to an upward bend of the region in front of the

mouth, the two pairs of feelers are directed forwards, an advantageous position for sense organs of the kind. The second or smaller pair, the *antennules*, conform markedly to the Y-diagram, and consist of a basal stalk and slender outer and inner branches. But it is by no means certain that we are justified in comparing the parts of this appendage with those

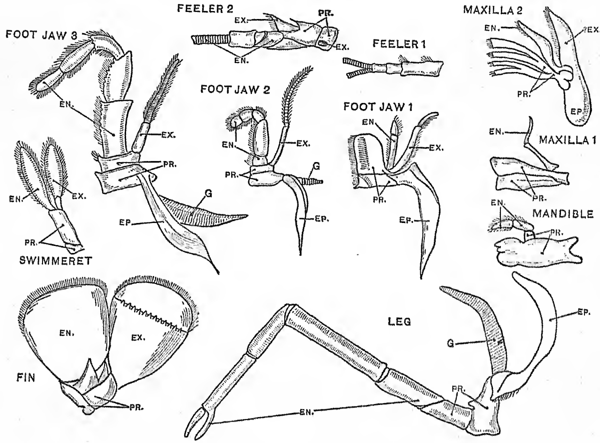


Fig. 248.—Appendages of Lobster (*Homarus vulgaris*)

PR. Base of appendage (protopodite); EN. inner branch (endopodite); EX. outer branch (exopodite), (the right-hand EX. in feeler 2 indicates excretory aperture; EP. gill-plate (epipodite); G, gill.

of the other ones, for it must be noted that the basal stem is here three-jointed instead of two-jointed as in all the other cases. The large feelers or *antennæ* conform to the type, for they consist of a two-jointed stalk, to which are attached a scale-shaped outer branch, and an excedingly long inner branch, which can be swept round so as to explore a considerable area in the neighbourhood of the body.

We have in the Lobster appendages an excellent example of the principles enumerated on p. 195, whereby structures of generalized type are modified in various ways to bring about special ends. These principles are: 1. variations in *shape*:

compare, *e.g.*, the antennæ, great pincers, and swimmerets; 2. variation in relative *size*: compare outer and inner branches in an average swimmeret and the side-pieces of the tail-fin; 3. variation in *number*: taking the Y-shape as the generalized type, the gill-plate is an addition in some cases, while in others the outer branch is much reduced or even absent; 4. *fusion* of parts: seen in the first abdominal appendages of the male.

This is a convenient point at which to compare some of the anterior appendages of Lobster with those of air-breathing Arthropods. One view is represented by the following table:—

Cockroach.	*Scorpion.*	*Centipede.*	*Peripatus.*	*Lobster.*
Antennæ	Absent.	Antennæ	Antennæ	Antennules
Absent	Cheliceræ	Absent	Absent	Antennæ
Mandibles	Pedipalpi	Mandibles	Jaws	Mandibles
1st Maxillæ	1st Legs	1st Maxillæ	Oral Papilla	1st Maxillæ
2nd Maxillæ	2nd Legs	2nd Maxillæ	1st Legs	2nd Maxillæ
1st Legs	3rd Legs	Poison Claw	2nd Legs	1st Foot-jaws
2nd Legs	4th Legs	1st Claw	3rd Legs	2nd Foot-jaws
3rd Legs	Operculum	2nd Legs	4th Legs	3rd Foot-jaws
Absent	Combs	3rd Legs	5th Legs	Great Pincers

It should be mentioned that many difficulties attend the comparison of segments and appendages in different groups, for one can seldom be quite certain that segments really correspond in different cases, and, even if they did, some appendages are apt to shift their position in the course of development.

The Lobster is protected by a firm shelly *exoskeleton* in the form of a horny layer which is thin where mobility is required, while elsewhere it is thick and hardened by the deposit of salts of lime. This strong suit of armour cannot increase in size as the animal grows, and the exigencies of the case are met by a process of moulting, which takes place frequently in young animals and at longer intervals later on. At the commencement of the operation a transverse split appears along the back, where the carapace joins the tail, and through this opening the animal painfully makes its way out. A sheltered corner is chosen for moulting purposes, and here the soft and defenceless creature remains till its new armour is properly developed and hardened.

The chief external characters have now been reviewed, and

the remainder may be taken in connection with the various systems of organs which are concerned, and which will be considered seriatim.

Digestive Organs (fig. 249).—These consist of (1) a symmetrical food-tube or *gut*, which runs back from the oval mouth situated on the under side of the head to the vent placed below the telson, and (2) of *digestive glands*. It will be noted that, as in Arthropods generally, the jaws are modified limbs, which work against one another from side to side and are entirely outside the mouth,

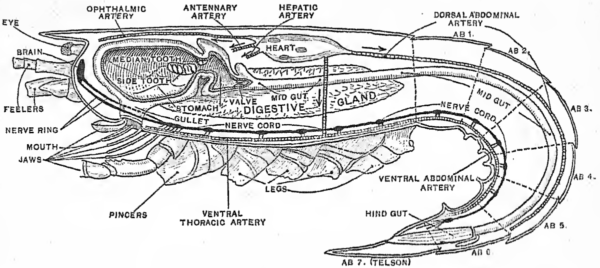


Fig. 249.—Side-dissection of Lobster (*Homarus vulgaris*), reduced. AB 1–AB 7, Abdominal segments.

which is bounded by upper and lower lips. It is found convenient to speak of the gut as being divided into three sections—a large fore-gut, a very small mid-gut into which the digestive glands open, and a long hind-gut. The distinction between these sections is based on the mode of development, for the first and last of them begin as pits which extend farther and farther inwards till they join the developing mid-gut, and form with it a continuous tube. It is not therefore surprising to find that the fore- and hind-guts, since they are formed by inpushing of the body-wall (see p. 261), are lined by a firm horny layer continuous with the exoskeleton, and that this layer is shed and replaced every time the animal moults. The *fore-gut* consists of a short *gullet* dilating into a very large *stomach*, divided into a cardiac section in front and a pyloric part behind. The stomach is said to be a "masticatory" one, for it contains a chewing apparatus or *gastric mill*, consisting of a number of hard pieces formed by thickening and calcification of the horny lining. These pieces

make up an elastic framework on which are borne two large lateral and one median tooth, and by the action of appropriate muscles these can be brought together so as to effectually chew anything that happens to be between them. The cavity of the pyloric part of the stomach is narrowed, and numerous interlacing bristles project from its walls, constituting a very effective "strainer", which prevents any but finely-divided particles from passing back into the short *mid-gut.* The lining of this part of the food-tube is soft, and a pair of large *digestive glands,* commonly called the liver, open into it. These organs are physiologically equivalent to liver and pancreas of a Vertebrate (see pp. 37 and 38). The *hind-gut* or intestine is a narrow tube continuous with the mid-gut, and possessing a firm lining raised up into longitudinal ridges.

The *Circulatory Organs* (fig. 350) conform to the Arthropod type already described in dealing with the Cockroach (p. 348), but the *heart,* instead of being a long slender tube, is a short broad sac, possessing only three pairs of valvular apertures, and suspended in the blood-containing pericardial cavity by means of fibrous cords. It is systemic (see pp. 308 and 348), *i.e.* contains purified blood, which it pumps through delicate branching arteries to the body at large. Sooner or later these arteries communicate with irregular spaces which ultimately open into a large *sternal sinus* running along the lower part of the body just within the body-wall. Meanwhile the blood has become impure by loss of much of its oxygen and receipt of carbon dioxide as a waste product. It therefore passes to the gills for purification, and, when this has been effected, is carried to the pericardial cavity, whence it passes into the heart through the valvular openings with which that organ is provided.

The *Excretory Organs,* by which nitrogenous waste is removed from the blood, consist of a pair of *antennary-* or *green-glands,* situated in the front part of the head and opening on the bases of the antennæ. Each is essentially a coiled tube, possibly equivalent to a nephridium (see p. 401).

The *Muscular System* is complex. The largest muscles are to be found in the tail, which is the organ by means of which the lobster is able to swim backwards through the water with great rapidity. Powerful *flexor muscles,* lying below the gut, bend the tail down and enable it to give its effective stroke, while

less powerful *extensor muscles*, lying above the gut, straighten it for another downward movement.

The Central Nervous System (fig. 249) consists of a *nerve-ring* surrounding the gullet, and a double *ventral cord* upon which numerous pairs of ganglia are developed. The upper part of the nerve-loop is thickened into a pair of brain or cerebral ganglia, by which the important sense organs of the head are supplied. The general arrangement conforms to that described in the Cockroach (see p. 349).

Organs of Sense are well developed, and many of them are in the form of specialized bristles or *setæ*, the soft axes of which are in communication with the skin by means of vertical canals which perforate the hard exoskeleton. Many of these setæ minister to the sense of *touch*, and this is especially true of those found on the antennules and antennæ. Organs of taste are not definitely recognized, though they probably exist on some of the appendages of the mouth. Certain peculiar spatula-shaped setæ present on the external branches of the antennules have to do with *smell*.

The extremely interesting *auditory organs* consist of two pear-shaped sacs, one of which is lodged in the basal joint of each antennule, and opens by a slit to the exterior. These sacs are really in-pushings of the skin, and they contain numerous specialized auditory setæ, and also grains of sand which have been introduced from the exterior. The chief interest attaching to these organs lies in the fact that they correspond to a stage in the development of more complex structures, such, *e.g.*, as the membranous labyrinths of Vertebrates, which start as pits in the skin (see p. 56).

The *visual organs* are in the form of two compound eyes situated on the front of the head near the antennules, and borne on stalks.

Development.—The Lobster passes through a *metamorphosis* in the course of its life-history, for it hatches out as a *larva*, which differs in many ways from the adult.

Crustacea, of which the Lobster has been described as a type, may be defined as aquatic Arthropods possessing two pairs of feelers (antennules and antennæ), and breathing organs (when such are present) in the form of gills. The appendages are typically forked. The class is subdivided in the following way:—

Sub-class 1.—Higher Crustacea (MALACOSTRACA).

Order 1. Stalk-eyed Crustacea (THORACOSTRACA).—Lobster, Cray-fish, Crab, Locust-Shrimp, Opossum-Shrimp, &c.

Order 2. Sessile-eyed Crustacea (ARTHROSTRACA).—Sand-Hoppers, Wood-Lice, &c.

Order 3. Intermediate Crustacea (LEPTOSTRACA).—Mud-Shrimps (Nebalia and its allies).

Sub-class 2.—Lower Crustacea (ENTOMOSTRACA).

Order 1. Barnacles (CIRRIPEDIA).—Ship-Barnacle, &c.

Order 2. Bivalve Crustacea (OSTRACODA).—Cypris, &c.

Order 3. Fork-footed Crustacea (COPEPODA).—Cyclops, Fish-Lice.

Order 4. Leaf-footed Crustacea (PHYLLOPODA).—Apus, Water-Fleas, &c.

Sub-class 1.—HIGHER CRUSTACEA (Malacostraca)

The following features, illustrated by the Lobster, are characteristic of the sub-class:—The body is made up of a constant and limited number of segments, each of which, with the exception of the last (or telson), bears a pair of appendages. In nearly all cases the segments are twenty in number, distributed as follows:—head, 5; thorax, 8; Abdomen, 7. The excretory organs typically present are antennary glands. The development is complex, and in most cases there is a larval form, differing markedly in appearance from the adult.

Order 1.—STALK-EYED CRUSTACEA (Thoracostraca)

In this order the head and thorax are fused together, and the eyes are usually situated on stalks. There are four sub-orders:—1. Ten-legged Crustacea (*Decapoda*), 2. Opossum-Shrimps (*Schizopoda*), 3. Locust-Shrimps (*Stomatopoda*), and 4. the Cumacea.

1. The *Decapoda* are so named because the last five pairs of thoracic limbs are seven-jointed locomotor organs, in which the outer branches are absent in the adult.

One large section of the sub-order is distinguished by the presence of a long and powerful tail, provided with a well-developed tail-fin. Among the British species here included are the following:—Lobster (*Homarus vulgaris*) (fig. 250), Rock-

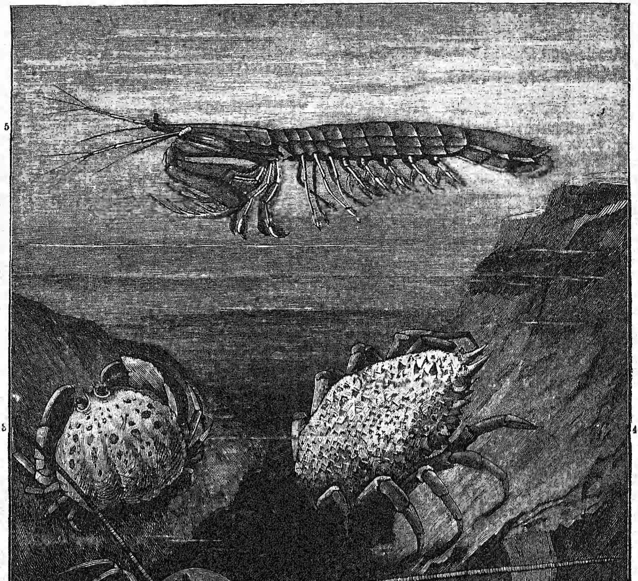


Fig. 250.—Mediterranean Crustacea

1, Lobster (*Homarus vulgaris*); 2, Bear-Crab (*Scyllarus arctus*); 3, Dromia Crab (*Dromia*);
4, Spider-Crab (*Maia squinando*); 5, Locust-Shrimp (*Squilla mantis*)

Lobster (*Palinurus vulgaris*) (fig. 251), Norway Lobster (*Nephrops Norvegicus*), Prawn (*Palæmon serratus*), Shrimp (*Crangon vulgaris*). The Crayfish (*Astacus fluviatilis*) is a fresh-water form.

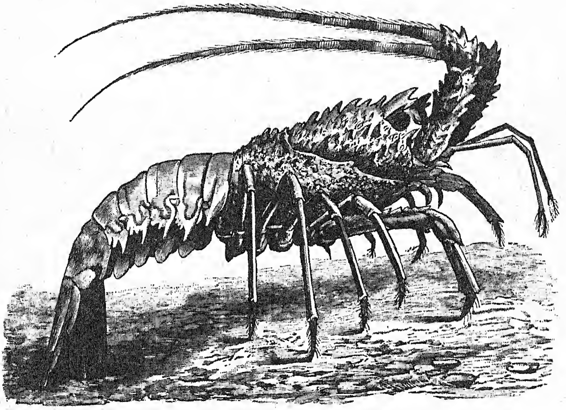


Fig. 251.—Rock-Lobster (*Palinurus vulgaris*)

Another section, including forms intermediate between the above and Crab, is formed by the *Hermit-Crabs* (fig. 252), which take up their abode in the empty shells of various sea-snails, and possess a soft unsymmetrical tail that has lost most of its appendages except the last pair. These have lost their original function of acting as swimming organs, and are modified into hook-like structures, by which the hermit-crab holds on to its house.

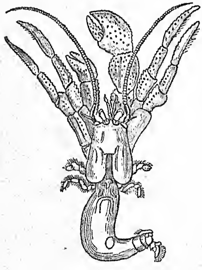


Fig. 252.—A Hermit-Crab (*Pagurus Bernhardus*), removed from its dwelling

The last section of the Decapods includes the true *Crabs* (fig. 250), in which the cephalo-thorax is very broad, and the tail so much reduced as to be useless as a swimming organ. Among British species may be noted the Edible Crab (*Cancer pagurus*) and the Shore Crab (*Carcinus mœnas*).

2. The *Opossum-Shrimps* (Schizopoda) are small marine forms

often found swimming in large shoals, and superficially resembling ordinary shrimps, though of much smaller size. They differ, however, from these in many important particulars, among which may be mentioned the delicate nature of the shield covering the cephalo-thorax, to which at least one thoracic segment is not united. There are, further, eight pairs of closely similar thoracic legs, provided both with outer and inner branches. The commonest British genus is *Mysis* (fig. 253), which so closely resembles a

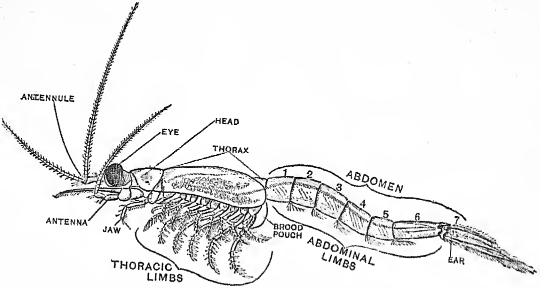


Fig. 253.—Opossum-Shrimp (*Mysis*), enlarged

stage in the development of the Lobster that this is spoken of as the "Mysis stage". Closed auditory sacs are present in its tail.

3. *Locust-Shrimps* (Stomatopoda) are much larger (fig. 250) than the members of the last sub-order, and are commonest in tropical seas, where they may attain a length of as much as 8 inches or more. The cephalo-thorax is small, for not only does it not include the last three thoracic segments, but it does not have to shelter the gills, as these are attached to the appendages of the broad well-developed abdomen. The thoracic appendages are remarkable, for the first five pairs of them are modified into foot-jaws, of which the second are extremely large and modified as seizing-limbs (fig. 250). So strikingly do they resemble the first pair of legs of the Praying Mantis (see p. 381), which have a similar function, that these Crustacea are often known as "Mantis-Shrimps". The last three pairs of thoracic appendages are leg-like, and possessed of both outer and inner branches. Two species are not uncommon in the Channel Islands (*Squilla Desmaresti* and *Squilla mantis*). Like

the other members of the sub-order, they are burrowing forms found in shallow water.

4. The sub-order *Cumacea* includes small shrimp-like forms (fig. 255) which live in shoals, and inhabit fairly deep parts of the sea where the bottom is of sand. The cephalo-thorax is even more

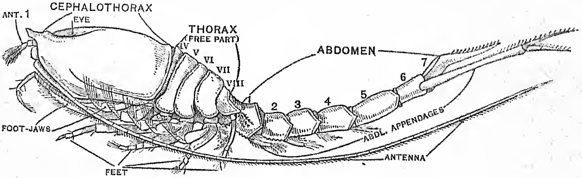


Fig. 254.—*Cuma* (enlarged). ANT. 1, Antennule IV–VIII, posterior thoracic segments; 1–7, abdominal segments.

limited than in the Locust-Shrimps, for the last five thoracic segments are not united with it. Some at least of the thoracic limbs possess outer as well as inner branches, and the two compound eyes are stalkless and sometimes fused together.

Order 2.—Sessile-eyed Crustacea (Arthrostraca)

The order includes a large number of comparatively small Crustacea, in which, as a rule, only one thoracic segment is fused to the head, and there is consequently no great armour-covered cephalo-thorax, as in a Crab or Lobster. The head-appendages correspond to those of a Lobster, but the thorax possesses only one pair of foot-jaws, its other appendages being seven pairs of legs, none of which are provided with pincers. There are usually six pairs of limbs on the abdomen. The eyes are devoid of stalks, *i.e.* are sessile

Two sub-orders are recognized, one containing laterally-flattened animals (Amphipoda), and the other forms which are flattened from above downwards (Isopoda).

1. The most typical members of the Amphipoda (fig. 255) are springing forms, of which the Sand-Hopper (*Talitrus locusta*) is a good example. During the summer months this may often be seen in leaping myriads between tide-marks on sandy shores. Its appearance suggests a strongly-curved flattened shrimp. Very similar in character are the species of the genus *Gammarus*, common in shallow water, both salt and fresh. The curious

Whale-Louse (*Cyamus ceti*) is exceptional among the members of the sub-order in having its body flattened from above downwards, and it is found parasitic on the skin of whales, to which it is enabled to hold fast by means of strongly-hooked legs. The abdomen is reduced to a mere stump entirely devoid of appendages. The weird-looking Skeleton Shrimps (*Caprella*) are also distinguished by the presence of a much-reduced abdomen. They are found climbing like monkeys among the branching colonies of various zoophytes.

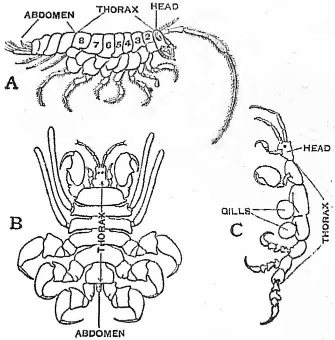


Fig. 255.—Amphipods (enlarged)

A, Sand-Hopper (*Talitrus locusta*); 2-8, last seven segments of thorax, the first is fused with the head. B, Whale-Louse (*Cyamus ceti*). C, Skeleton Shrimp (*Caprella*).

2. *Isopods* (fig. 256) differ from Amphipods in being flattened from above downwards, while the abdomen is shortened and bears plate-like appendages. Most of the species are marine, and of these *Cirolana*, *Idotea*, and *Sphæroma* may be taken as typical British genera. Some, however, are fresh-water, as, *e.g.*, the common native Fresh-water Shrimp (*Asellus aquaticus*), distinguished by its long limbs; and still others are terrestrial, of which the most familiar is the Wood-Louse (*Oniscus murarius*), commonly found under damp stones and in similar places. Some of the Isopods are curiously modified to fit them for a parasitic life, and these will be mentioned elsewhere.

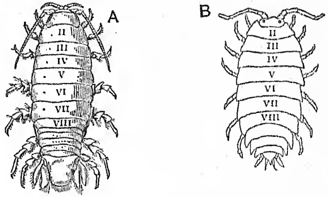


Fig. 256.—Isopods (enlarged)

II-VIII, Free segments of thorax, the first is fused with the head. A, *Cirolana borealis*; B, Wood-Louse (*Oniscus murarius*).

Order 3.—Intermediate Crustacea (Leptostraca)

The *Mud-Shrimps*, including *Nebalia* (fig. 257) and allied genera, form a restricted but interesting group of small marine shrimp-like creatures found in all parts of the world. These forms have attracted a good deal of attention, because they are a connecting-link between the higher and lower Crustacea, and some zoologists place them in a separate sub-class. Like the higher Crustacea they are composed of a definite and limited number of segments, in this case, however, twenty-one instead of twenty, for the abdomen has an extra segment, and the excretory organs include antennary glands. They also agree with stalk-eyed forms as regards their visual organs. But on the other hand all the segments of the thorax are free, though it and part of the abdomen are covered by a bivalve *shield* which grows back from the head, and the eight pairs of thoracic appendages are leaf-like, as in some of the lower Crustacea. The first four segments of the abdomen bear forked appendages as in certain other of the lower Crustacea (Copepoda), a further agreement with which is found in the fact that the tail also is forked. In addition to antennary glands they possess other excretory structures (shell-glands) resembling those of lower forms. On the whole it may be taken as fairly certain that the Leptostraca resemble in many points the ancestral stock from which the various groups of higher Crustacea have diverged.

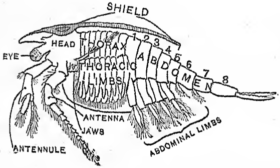


Fig. 257.—Mud-Shrimp (*Nebalia*), enlarged Left half of shield cut away.

Sub-class 2.—Lower Crustacea (Entomostraca)

This is an exceedingly large and greatly diversified group, including both marine and fresh-water forms, of which the large majority are very small, and which play a very important part in nature as the food of higher animals. There is a very large amount of variation as regards the number of segments, and a similar wide range in the nature of the appendages, which are often flattened and leaf-like, though in other cases they may exhibit

the bifurcated type which we have found to be characteristic of higher forms. There is no gastric mill, and it is common to find three functional eyes present in the adult, two compound and one simple. As a general rule the embryo hatches out as a *Nauplius larva* (fig. 258), which typically possesses an unsegmented ovoid body and three pairs of appendages by means of which it swims, these corresponding to the antennules, antennæ, and mandibles of the adult. A larva of this kind is rarely found among higher Crustacea.

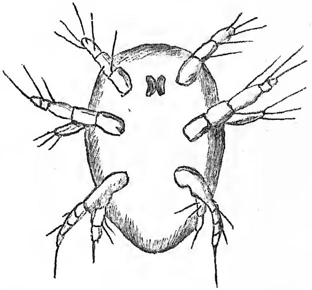


Fig. 258.—A Nauplius larva (seen from below and greatly enlarged). Note unpaired eye and three pairs of appendages

The four included orders have already been enumerated; *i.e.* 1. Barnacles (*Cirripedia*); 2. Bivalve Crustacea (*Ostracoda*); 3. Fork-footed Crustacea (*Copepoda*); and 4. Leaf-footed Crustacea (*Phyllopoda*).

Order 1.—Barnacles (Cirripedia)

This is a remarkable group of marine Crustacea, all of which are either fixed or parasitic, and have undergone considerable, or, it may be, profound modifications resulting from their mode of life. Leaving out of consideration the degenerate parasitic forms, which will be dealt with elsewhere, there remain the widely-distributed group of Barnacles, of which the best known are the Ship-Barnacle (*Lepas anatifera*), and the Acorn-Barnacles (species of *Balanus*), which encrust the rocks between tide-marks on the coasts of Britain.

The characters of the group will best be understood by briefly describing the Ship-Barnacle (*Lepas anatifera*), large numbers of which are often found attached to floating objects which have been cast up on our shores, and which in old days were a serious nuisance to sailors, as they attached themselves to the wooden bottoms of ships in such vast numbers as to impede movement.

The *Ship-Barnacle* (fig. 259) is attached by means of a long soft *stalk* covered with corrugated skin, and upon this is borne a

flattened oval swelling, covered by a number of shelly pieces, suggesting at first sight that the animal is a kind of Mollusc. A closer examination will show that these pieces are attached to a couple of soft flaps united together on one side, but leaving between them on the other side a slit through which, in a living specimen, a bundle of hairy-jointed filaments will from time to time protrude and spread out, being drawn back again immediately afterwards. These tendril-like structures, or *cirri*, which act as a kind of casting-net, whereby food is swept into the mouth, are six pairs of bifurcated appendages, and their jointed nature shows that we are dealing, not with a Mollusc, but with an Arthropod. To a strong imagination they might suggest feathers in a vague way, and they are probably responsible for the well-known natural-history legend, according to which the Solan Goose ("Barnacle" Goose) develops from a barnacle, the chicks falling into the water when sufficiently grown to look after themselves. The specific name of the barnacle, "anatifera" (L. *anser*, a goose; *fero*, I bear), has reference to this old belief. On removing the shell, and the flaps to which it is attached, the soft body of the animal will be found, consisting mainly of *thorax*, to which the tendril-like appendages are attached. The *abdomen* is reduced to a limbless process ending in a long filament. The under (ventral) side of the thorax is turned upwards, and at its front end will be found the *mouth*, provided with upper lip, mandibles, and two pairs of maxillæ. No eyes or feelers are visible, but study of the development shows that the animal is fixed by its head, which has grown into a long stalk, at the end of which were situated the short antennules, that served as organs of attachment from which the sticky secretion of special "cement glands" was poured out. The antennæ, present in the larva, entirely disappear in the adult. Huxley has graphically compared a barnacle to a man lying upon his back and kicking his food into his mouth.

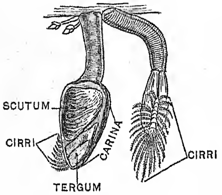


Fig. 259.—Ship-Barnacles (*Lepas anatifera*), reduced

Acorn-Barnacles agree essentially in structure with the ship-barnacle, but do not possess a stalk, and there is an extra protection to the body in the form of a sort of shelly cup made up

of a number of pieces fused together. The appearance of the body within the cup has no doubt suggested the name "acorn"-barnacle, but the resemblance is remote.

Order 2.—Bivalve Crustacea (Ostracoda)

These are small Crustacea common both in salt and fresh water, especially where the bottom is muddy. Examination of the mud from almost any pond will often reveal the presence of

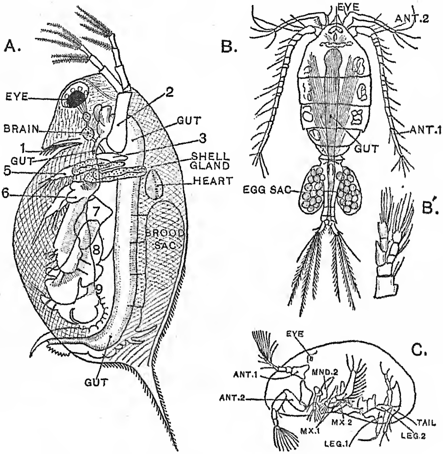


Fig. 260.—Small Fresh-water Crustacea (much enlarged to various scales)

A, Water-Flea (*Daphnia*): 1, antennule; 2, antenna; 3, mandible; 5–9, flattened thoracic appendages. B, Cyclops (seen from above): ANT.1, antennule; ANT.2, antenna. B′, Swimming-foot of Cyclops, showing the typical forked shape. C, Mussel-Shrimp (*Cypris*): ANT.1, antennule; ANT.2, antenna; MND., mandible; MX.1, first maxilla; MX.2, second maxilla.

one or more *Mussel-Shrimps*, species of the typical genus *Cypris* (fig. 260), which therefore furnishes a convenient type. The most striking feature is the presence of a *bivalve shell*, comparable to the carapace of other forms and entirely enclosing the body, reminding one of the arrangement characteristic of bivalve Molluscs (p. 311). The resemblance is enhanced by the fact that the two valves of the shell can be closed by the contraction

of an adductor muscle and opened by the action of an elastic ligament. The body of the animal is extremely short, and the abdomen is a mere vestige. Segmentation is only indicated by the appendages, of which there are but seven pairs, five belonging to the head (two pairs of feelers and three pairs of jaws), and the remainder, in the form of narrow pointed legs, to the *thorax*. These legs can be protruded from the shell, and so can the well-developed feelers which are used as organs of locomotion, as in a nauplius larva. There is an unpaired eye on the front of the head.

Order 3.—FORK-FOOTED CRUSTACEA (Copepoda)

This order is a vast assemblage of species which are for the most part minute, and occur in all parts of the world both in salt and fresh water. Many of them are found in huge shoals at the surface of the open sea, forming a variety of *plankton*, as such assemblages are termed, which furnishes an important item in the food of whales and of many fishes, such as the herring. The fishes, however, do not have it all their own way with the Copepods, for attached to their eyes and gills may often be found parasitic members of the order, which are often strangely modified. Leaving such forms out of consideration for the present, and turning our attention to free-living Copepods, we may take a common fresh-water genus, *Cyclops* (fig. 260), as a type of the order. It can be distinguished with the naked eye as an active whitish creature with a jerky mode of progression.

The body of Cyclops has not unaptly been compared in shape to half of a split pear, with the convex side dorsal and the stalk corresponding to a tail. The body is distinctly segmented, and the five *head-segments* are fused with one another and with the first thoracic segment. Then follow the five free segments of the *thorax* and the four narrow segments of the *tail*, the last of which bears a *tail-fork* provided with two bunches of bristles. Upon the front of the head is a single reddish *eye*, which has suggested the generic name of Cyclops; and there are the usual five pairs of head appendages, of which the first, *i.e.* the *antennæ*, are very large and employed as oars. The thorax bears four large pairs of forked *swimming-feet*, and the abdomen is limbless. The female, which is the sex commonly seen, usually has a pair of large *egg-sacs* attached at the base of the abdomen.

Order 4.—Leaf-footed Crustacea (Phyllopoda)

These are Crustacea of varying size, though none are very large, which are for the most part inhabitants of fresh water. The segments and appendages differ greatly in number in different cases, but those of the latter situated farther back than the head are characterized by their flattened leaf-like form. There are two sub-orders—1. Gill-footed Phyllopods (Branchiopoda), and 2. Water-Fleas (Cladocera).

1. *Gill-footed Phyllopods* possess a special interest, since they not improbably present many of the characters distinguishing the ancestral stock from which all the different groups of Crustacea are descended.

A typical genus is *Apus* (fig. 261), species of which are sometimes found in great abundance at various localities on the Continent, especially in flooded meadows. For the sub-order this form reaches a considerable size, being as much as 2 inches in length. It is of a greenish-brown colour, and though segmentation is not apparent in the head, the rest of the body is composed of a large number of obvious segments. The most striking feature is the presence of a broad thin *carapace*, which, arising from the head, extends backwards so as to cover the back and sides of the greater part of the body. The narrow posterior end of the abdomen remains uncovered by the carapace, and terminates in a pair of long jointed filaments. The *head* bears a minute pair of antennules, vestiges of antennæ, strong mandibles, and two pairs of maxillæ. A very large number of flattened lobed swimming-feet are attached to the *thorax* and front part of the *abdomen*. They are not limited in number to one pair per body-segment, as is the case with the majority of Crustacea. A typical *swimming-foot* consists of a number of small pointed inner lobes, and two larger outer lobes, of which one is a soft

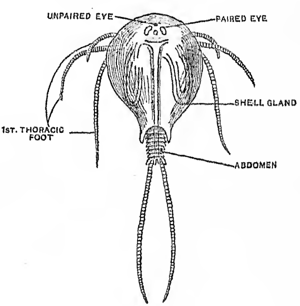


Fig. 261.—Apus

pear-shaped *gill*. Such a limb is regarded by many as the generalized type from which the varied kinds of appendages found within the class have been derived by modifications of different kinds (see p. 403). This may perhaps be so, but it is not always easy to recognize with certainty the equivalent parts in different Crustacean groups. All these swimming-feet in Apus are by no means exactly alike; *e.g.* some of the inner lobes of the first thoracic pair are drawn out into long filaments, liable at first glance to be mistaken for antennules and antennæ, while in the female the eleventh thoracic pair are partly modified into *brood-capsules* within which the eggs develop.

The *excretory organs* of Apus are not, as in the higher Crustacea, antennary glands, but coiled tubular *shell-glands* which open to the exterior upon the second maxillæ. Three *eyes* are placed close together on the top of the head—a small unpaired "nauplius eye" in the middle line, and a pair of compound eyes.

2. The *Water-Fleas* (Cladocera) are small active Crustacea, mostly inhabiting fresh water. The characters of the sub-order are well seen in the very common form *Daphnia* (fig. 260). The thorax and shortened abdomen are enclosed in a bivalve *carapace* which grows back from the head. The usual five pairs of appendages are borne by the head (except second maxillæ, which are absent), and of these the most remarkable are the large forked plume-like *antennæ* which are used as swimming organs. There are five pairs of flattened thoracic *swimming-feet*, something like those of Apus, but the short abdomen is limbless. It bends sharply round to the under surface and ends in a pair of curved bristles. When Daphnia is examined alive under the microscope, an oval pulsating sac will be noticed near the dorsal surface. This is the *heart*. The coiled *shell-gland* is also easily seen, and the large *compound eye* is a conspicuous object. It lies in the front of the head, and has been formed by the fusion of two lateral eyes. It is constantly in a state of trembling movement. A small *nauplius eye* is present a little farther back.

CLASS 6.—KING-CRABS (XIPHOSURA)

This small but interesting class includes only the *King-Crab* (*Limulus*), a large marine Arthropod living in shallow water in the East Indies and the warmer parts of the West Atlantic and

West Pacific. There has been much discussion as to its classificatory position, some authorities including it in the Crustacea and others in the Arachnida. In support of the latter view it has been shown that, allowing for the fact that one is a marine and the other a terrestrial animal, there is a very remarkable agreement between King-Crab and Scorpion. As, however, the matter is by no means settled, it appears better for the present to assign Limulus a class of its own.

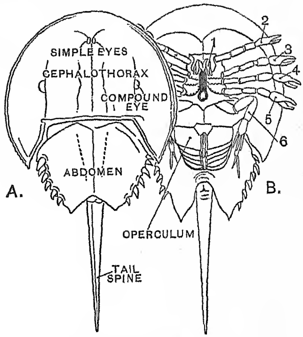


Fig. 262.—King-Crab (*Limulus*), reduced

A, From above; B, from below. 1, Cheliceræ; 2–6, legs. The mouth is seen in B as a darkly-shaded slit between the bases of the legs.

The body of a King-Crab (fig. 262) is divided into two regions, a *cephalo-thorax* covered above by a large horse-shoe-shaped shield, and a similarly protected *abdomen* to which a long movable *spine* is attached behind. A pair of *simple eyes* are situated on the top of the front shield towards the anterior end, and farther back there are a pair of large *compound eyes*, placed at a greater distance from each other.

Upon the under side the appendages can be seen, the first of which are the small *chelicerœ*, provided with pincers and situated in front of the mouth. Then follow five pairs of *legs* apparently equivalent to the pedipalps and legs of the Scorpion. The first of them are provided with pincers in the female, and the next three pairs are similarly provided in both sexes. The ends of the last pair are curiously modified so as to fit them for digging. The bases of these leg-like appendages are provided with biting projections, which between them almost surround the elongated *mouth*. The remaining appendages are six plates, obviously formed by the fusion of pairs of appendages and borne by the abdomen. The first of them is equivalent apparently to the operculum of Scorpion (p. 386), and the second to the combs of that animal. All but the first bear numerous gill-folds.

Class 7.—SEA-SPIDERS (Pycnogonida)

These are widely distributed marine Arthropods, mostly of small size. Some zoologists associate them with Arachnida, but their real affinities are as yet undetermined. Taking such a typical form as the Shore Pycnogon (*Pycnogonum littorale*), we see (fig. 263) that the spider-like appearance is due to the presence of four slender pairs of thoracic limbs, in front of which are three pairs of smaller appendages, of which the first bear pincers and the last are used by the males for carrying the eggs about. The mouth is situated on the end of an elongated snout, and there are four simple eyes.

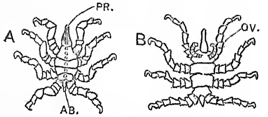


Fig. 263.—Shore Pycnogon (*Pycnogonum littorale*)
A, From above; B, from below. AB. Abdomen; OV. egg-bearing appendages; PR. snout.

CHAPTER IX

STRUCTURE AND CLASSIFICATION OF SEGMENTED WORMS, SIPHON-WORMS, WHEEL-ANIMALCULES, MOSS-POLYPES, AND LAMP-SHELLS

SEGMENTED WORMS (ANNELIDA)

This phylum is a vast assemblage of marine, fresh-water, and terrestrial worms and leeches, which agree with one another in the possession of a bilaterally symmetrical body divided into numerous similar segments, and in the absence of jointed appendages like those of the Arthropoda. The body-wall consists of skin with underlying layers of muscle; there is a muscular pharynx; and the excretory organs are in the form of numerous pairs of convoluted tubes (nephridia), each of which, in typical cases, opens on the one hand to the exterior, and on the other into a body-cavity of the same nature as that found in Vertebrates (see p. 42). The phylum is divided into two classes: 1. Bristle-Worms (Chætopoda), and 2. Leeches (Discophora).

CLASS I.—BRISTLE-WORMS (CHÆTOPODA)

A good typical example of this group is the so-called *Sea-Centipede* (fig. 264), a name popularly applied to several species of the genus *Nereis* which are found upon our coasts. The body is bilaterally symmetrical and obviously divided into a large number of *segments*, all very similar to one another except those at the extreme ends. There are clearly none of the jointed lateral appendages which are so characteristic of Arthropods, their place being taken by hollow "foot-stumps" (parapodia), of which each segment bears a pair. The nearest approach to such foot-stumps among the Arthropoda are the legs of Peripatus (p. 399). Examination by means of a lens will show that each *foot-stump* is divided into an upper lobe and a lower lobe near each of which

is a short feeler or cirrus. Imbedded in each lobe is a bundle of bristles or *setæ*, of which one is much larger and stronger than the rest, though it only just projects from the surface of the body.

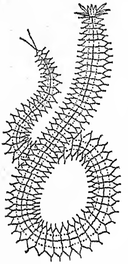


Fig. 264.—A Sea-Centipede (*Nereis*), diagrammatic

These setæ are of great use in locomotion, acting as holdfasts by means of which the body gets a purchase on sand or the like. They exhibit all sorts of variations in shape. The *head*, upon the under side of which is the mouth, consists of a mouth-segment, and a projection in front of the mouth which may conveniently be called the head-lobe. From the upper side of this lobe, near the front, spring two short tentacles, and there are two much larger "palps" which arise from the under side of the same region rather farther back. Not only do these last-named structures act as sensory organs, but they also serve as lips to some extent. Upon the upper side of the head-lobe are four simple *eyes*, looking like black specks. The mouth-segment is provided with four pairs of slender feelers, which are apparently of the same nature as the cirri of the trunk-segments. None of the appendages are converted into jaws, a feature which is so characteristic of Arthropods, though it may be remembered that in the member of that group which comes nearest to the Annelida, *i.e.* Peripatus, there is only one pair of these structures (see p. 399). Turning now to the last tail segment, which is perforated by the opening of the intestine, we shall find that it is comparatively small and devoid of foot-stumps, though it possesses one pair of long backwardly-directed cirri.

Internal Structure of Nereis (fig. 265). The *body-wall* presents very primitive features, reminding one of Peripatus (see p. 401). It consists of the *skin*, which is practically little more than a thin epidermis covered by a tough cuticle, and two underlying *muscle-layers*, of which the outer is composed of fibres which run transversely, while the other consists of four prominent bands in which the fibres have a longitudinal direction. Closely connected with the body-wall, though scarcely perhaps forming part of it, is an oblique sheet of muscle on each side, made up of numerous fan-shaped sections, which take origin near the sides of the ventral nerve-cord and spread out in the foot-stumps, to which they are attached and serve to move.

Digestive organs.—On cutting open the body of Nereis we find that it is traversed by a straight *food-tube*, between which and the body-wall is a large *body-cavity* which corresponds with that of Vertebrates in being a cœlom, *i.e.* a body-cavity which contains a lymph-like fluid and communicates with the exterior by excretory tubes (see p. 428). The segmentation prominent externally is emphasized internally by the division of the body into a series of compartments by transverse partitions attached

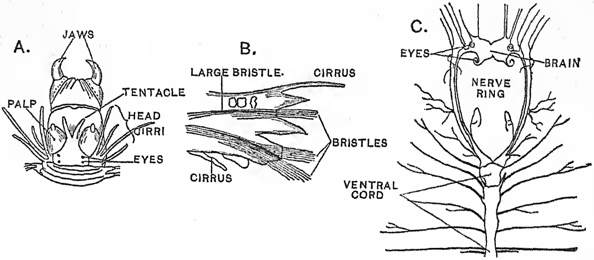


Fig. 265.—Structure of Sea-Centipede (*Nereis*), enlarged to various scales
A, Head, with mouth-cavity everted and jaws protruding. B, A foot-stump (parapodium). C, Front part of nervous system.

to the body-wall at the places where grooves mark off the segments from one another. These partitions are also attached to the gut, and keep it in place, thus acting like the folds known as *mesentery* in Vertebrates. The food-tube or *gut* consists successively of mouth-cavity, pharynx, gullet, and intestine. An interesting peculiarity of the short mouth-cavity is found in the fact that it can be everted, or turned inside out, by means of appropriate muscles, and under those circumstances the absence of limb-jaws is made up for by the protrusion of a pair of hard horny jaws carried on the inner side of the pharynx and acting as a very efficient pair of pincers for seizing food. The everted mouth-cavity is restored to its normal position by certain muscles attached to its wall which draw it back. The pharynx has extremely thick walls, another point in which one is reminded of Peripatus (see p. 401). The gullet is short and narrow, and a pair of glands open into it. The intestine, which makes up the greater part of the gut, is thin-walled.

Circulatory Organs.—We can here distinguish, as in a Verte-

brate (see p. 38), between a blood-system and a lymph-system. The *blood-system* contains red blood, the colour being due to the presence of the same pigment (hæmoglobin) as that found in Vertebrates (see p. 265), though here it is dissolved in the plasma, or liquid part of the blood, and is not contained in corpuscles. The vessels which carry the blood form a closed system, the smaller branches of which break up into capillary net-works. No heart is present, and the pumping is effected by the larger vessels, along which waves of contraction pass, forcing the blood onwards, much as digesting food is carried onwards in an intestine by peristaltic contraction (see p. 37). The two most important blood-vessels are longitudinal in direction, one being a *dorsal vessel* above the gut and the other a *ventral vessel* below it. The blood flows forwards in the dorsal vessel and backwards in the ventral one. From these two chief trunks transverse vessels are given off regularly in segmental order, and the branches of these break up into net-works in the substance of the various organs.

The *lymph system* consists of the body-cavity, and the colourless lymph which it contains consists of plasma in which float numerous irregular lymph corpuscles (see p. 42).

Respiration is effected in the body-wall, which is richly provided with blood-vessels branching just below the epidermis. Most likely the foot-stumps play an important part in regard to this function.

Excretion of nitrogenous waste is performed by the excretory tubes or nephridia, of which a pair are present in almost every segment. Each of these organs is essentially a ciliated tube which begins by a small funnel placed just in front of one of the partitions which cross the body-cavity, runs back to pierce this, and ultimately opens to the exterior on the under surface of the body close to the base of a foot-stump.

The *Central Nervous System* consists of a *nerve-ring* encircling the commencement of the gut and a *ventral nerve-cord*, resembling, therefore, the corresponding organs of a lobster. The nerve-ring is thickened dorsally into a closely-fused pair of brain- or cerebral-ganglia, and the ventral cord, which is of double nature, swells into a pair of closely approximated ganglia in each segment.

Sense Organs.—The cirri and head-tentacles are presumably organs of *touch*. It is likely that the palps borne on the head have to do either with *taste* or *smell*, or it may be with both.

There are no auditory organs, and the four simple *eyes* have already been mentioned.

The Bristle-Worms are subdivided into three orders:—1. Many-bristled Worms (Polychæta); 2. Few-bristled Worms (Oligochæta); and 3. Simple Segmented Worms (Archiannelida).

Order 1.—Many-bristled Worms (Polychæta)

This order embraces an enormous number of marine worms, possessing a considerable number of setæ and agreeing in many other particulars with Nereis, which is a type of the order. Over thirty families are recognized, grouped into seven sub-orders, but it will be sufficient for our purpose to divide the order into two groups:—1. Free-living Polychætes (Errantia), and 2. Sedentary Polychætes (Sedentaria).

1. *Free-living Polychætes* (Errantia), of which Nereis is a good example, are carnivorous forms which move actively about in pursuit of their prey, swimming, crawling, or burrowing. To this habit their structure corresponds, for the locomotor organs (foot-stumps) are well-developed, as also is the head-lobe, with its eyes and feelers. The pharynx can be protruded in the way described for Nereis and is usually armed with horny jaws.

Only one or two British forms can be mentioned here in addition to Nereis. Species of *Polynoe* are common on our shores, and these can readily be identified by their elongated oval form and the presence of a double series of scales (elytra) on the upper surface, which appear to be organs of respiration. Built on somewhat the same lines is the conspicuous "Sea-Mouse" (*Aphrodite*), the plump body of which attains a considerable size. The setæ are of several kinds, and very numerous: some of those arising from the upper divisions of the foot-stumps are much elongated and beautifully iridescent. As in Polynoe, there is a double row of elytra, but they are here covered by a tough membrane consisting of numerous small setæ matted together.

2. *Sedentary Polychætes* (Sedentaria) either have limited powers of movement, and inhabit permanent tubes, or else are burrowing forms, which pour out a sticky fluid from the skin that glues together the sand or mud surrounding them into a sort of temporary case. They live upon vegetable matter. The head-

region may either be much reduced and devoid of appendages, or else, in the forms inhabiting firm permanent tubes, provided with numerous tactile filaments and large branching gills. The foot-stumps are not so well developed as in the free-living forms, and the pharynx is not armed with horny jaws or teeth.

The *Lugworm* (*Arenicola piscatorum*) (fig. 266) is well known as a burrowing form highly esteemed as bait. It makes U-shaped passages in the mud or sand, near which may be seen coiled "worm-castings" made up of sand and undigested food, which have been voided from the body. The most striking external feature consists in the presence of branching *gills* projecting from the middle region of the body. *Cirratulus* is a long cylindrical worm often to be found buried in the sand underneath stones. Its locomotor organs are much reduced, and the dorsal cirri are slender elongated filaments which project above the surface of the sand and act as gills, the active wriggling movements which they constantly execute giving them a resemblance to small red worms, for which they are often mistaken. Another common shore form is *Sabellaria*, which glues sand-grains together into a tube. Large numbers of these animals live associated together, and their tubes often form compact masses of considerable extent. Every-one must have noticed at the sea-side small convoluted limy tubes encrusting oyster-shells or stones. These belong to *Serpula*, a particularly beautiful form, in which the head bears two brightly-coloured bunches of gill-filaments. One of these is converted into a conical horny stopper, which closes the opening of the tube when the worm has withdrawn itself. *Spirorbis* is a related but much smaller form, in which the tube is coiled into a flat spiral. Large numbers of these may often be found adhering to brown sea-weeds.

Fig. 266. Lugworm (*Arenicola piscatorum*)

Order 2.—Few-bristled Worms (Oligochæta)

These are segmented worms which for the most part live in fresh water or burrow in the earth. They lack feelers and foot-stumps, while gills are but rarely present. Locomotion is effected

by the contractions of the muscular body-wall aided by the setæ, which are comparatively few in number. The pharynx is not armed with horny jaws.

A common fresh-water form is the Red River-Worm (*Tubifex rivulorum*), a small creature often to be seen in ponds, partially imbedded in the mud. Large numbers often occur together, making up conspicuous red patches, that disappear when the mud is disturbed, which means that the worms have withdrawn themselves into it.

Earth-Worms are found in almost all parts of the world, and there are a number of British species, of which the Common Earth-Worm (*Lumbricus herculeus*) is usually taken as a type. The *head* consists of a mouth-segment and a head-lobe, and is entirely devoid of eyes or feelers. The *trunk* is divided into a large number of clearly-defined segments, and not very far from its front end is a band-like thickening, the *girdle* (clitellum), which has to do with the formation of capsules in which the eggs are enclosed. The popular notion is that it is the result of injury by the spade. If an earth-worm be passed, tail first, between the finger and thumb, a distinct feeling of roughness will be experienced, due to the presence of four double rows of setæ, the tips of which just project above the skin.

Order 3.—Simple Segmented Worms (Archiannelida)

A small number of simple marine worms constitute this order, and it is probable that to some extent at least they possess the characters of the ancestral stock from which all segmented worms are descended. It must not be forgotten, however, in this connection, that simplicity of structure is often the result of degeneration, and it is possible that some of these creatures may be on the down-grade. There is a small head-lobe, and most of them have a fairly long trunk. The segmentation of the body is well marked by the presence of encircling grooves, and also by rings of cilia, which serve as locomotor organs in place of setæ and foot-stumps, here entirely absent. Probably the most primitive of the Archiannelids is the minute *Dinophilus*, of which more than one species occur on our coasts. It presents certain points of affinity to the unsegmented worms, which will be considered later. *Polygordius* is a slender cylindrical red worm found,

among other places, in the Mediterranean, and also recorded from the British coasts. It is more complex in structure than Dinophilus.

A word of explanation may be here necessary of the statement that the simplicity of these creatures is possibly not primitive, but the result of degeneration. Take, for example, the absence of setæ as a character to be criticised from the two points of view. This negative character may mean that the ancestors of the group did not possess setæ, and, if so, the character is a primitive one. To maintain, on the other hand, that the absence of setæ is due to degeneration is to suppose that the ancestral forms did possess setæ, which have been lost in the course of evolution. That such a thing is possible becomes clear if we compare Nereis with some of the sedentary Polychætes and with earth-worms. In the first case well-developed foot-stumps provided with setæ are present; in the second, these structures are reduced; while ordinary earth-worms possess setæ but no parapodia. A further reduction would give the condition found in Polygordius (and some Oligochætes).

CLASS II.—LEECHES (DISCOPHORA)

Leeches are typically fresh-water or terrestrial forms, though some of them are marine. Most of them are blood-sucking parasites. The average characters of the group are conveniently exemplified by the common Medicinal Leech (*Hirudo medicinalis*). The elongated body, capable of considerable variation in form, is flattened from above downwards, and is provided with a *sucker* at each end, by alternate attachment of which looping movements can be performed, much as in a looper caterpillar (see p. 364). Both the suckers face downwards, and the mouth is in the middle of the front one, while the intestine opens outside and just above the hinder one. Encircling grooves divide the body into a large number of narrow rings, several of which go to a segment. Feelers, foot-stumps, and setæ are entirely absent. Ten simple *eyes* may be seen as black specks on the front end of the body, placed close to the margin of the upper surface. The well-known three-rayed bite of the leech is made by the finely-toothed margins of three horny jaws with which the muscular pharynx is provided.

Although the Medicinal Leech does occur in this country, a

much commoner native form is the Horse-Leech (*Aulastomum gulo*), which has smaller jaws and does not attack animals, preying only upon small aquatic animals. Some of the Leeches do not possess jaws, and these are grouped in a special subdivision of the class. Many of them are parasitic upon fish.

SIPHON-WORMS (GEPHYREA)

This group is retained as a matter of convenience to include a number of worm-like animals, little known except to professed naturalists, and some of which appear to be related to Annelida. None of them exhibit other than feeble traces of segmentation.

The *Bristle-Tail* (*Echiurus*) (fig. 267) has a stout cylindrical body covered by tough skin. The *mouth* is situated on the under surface at the base of a narrow forward projection known as the *proboscis*, which must be regarded as a head-lobe. It is used both as an organ of locomotion and in procuring food, a deep groove running along its under side to the mouth. Among the characters which show affinity to the Bristle-Worms may be mentioned the possession of *setæ*, one or two rings of which encircle the hinder end of the body, while there are a pair of hook-like bristles imbedded in the skin not far behind the mouth. Behind them are the openings of two pairs of excretory tubes (brown tubes) comparable to the nephridia of segmented worms.

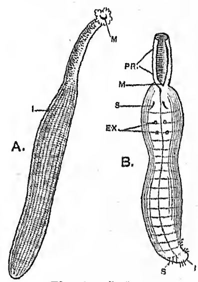


Fig. 267.—Gephyrea
Siphon-Worm (*Sipunculus*): M, mouth; I, intestinal aperture. B, Bristle-tail (*Echiurus*): PR., proboscis; M, mouth; S, S, setæ; EX, excretory apertures; I, intestinal aperture.

The *Siphon-Worm* (*Sipunculus*) (fig. 267), numbers of which are sometimes cast up on the shore by storms, burrows in the sand, which it swallows for the sake of the contained organic debris, in this respect reminding one of the earth-worm, to which also our native species have a slight external resemblance, though they differ markedly in the absence of setæ and body-segments. Examination of a living Sipunculus shows that the animal possesses the peculiar power of turning the narrow front part of its body outside in (introverting it), this and the reverse process often being rapidly repeated for a considerable number of

times. When the body is fully extended the *mouth* will be seen at its tip surrounded by a series of short, grooved *tentacles*. This creature departs further than Echiurus from the typical segmented worms, for it is entirely destitute of setæ, and the convoluted intestine opens to the exterior not far from the front end of the body on the upper surface.

WHEEL-ANIMALCULES (ROTIFERA OR ROTATORIA)

The Wheel-Animalcules are minute transparent animals mostly found in fresh water, though some are marine, and others are to be found on damp earth and vegetation. They present great diversity in form and structure, and as microscopic objects are unsurpassed for beauty and interest. Unfortunately their true affinities are yet to seek, but as likely as not they are the degenerate descendants of higher worms, and are to be looked upon as permanent larvæ, the original adult form having been dropped out of the life-history. That such a thing is possible is shown by the case of the Axolotl among Amphibia, to which reference has already been made (p. 249).

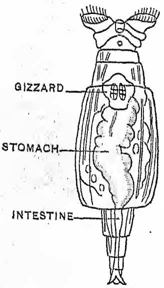


Fig. 268.—Rose-coloured Rotifer (*Philodina roseola*), greatly enlarged

A common and beautiful fresh-water form, which will serve as a type, is the *Rose-coloured Rotifer* (*Philodina roseola*) (fig. 268). The elongated body is covered by a firm cuticle, and this is marked by transverse furrows so as to give a deceptive appearance of segmentation. The posterior end of the body tapers into a jointed tail ending in a pair of forceps, and by means of this region the animal is able to progress somewhat like a leech. When the rotifer is fully extended, a couple of prominences are seen at the front end which together constitute the *wheel-organ*. Each of them is fringed with a circlet of cilia, and as these move one after another in a very regular way a deceptive appearance of rotation is produced, suggesting the movement of a wheel. By means of this organ the animal is able to swim and it also sets up currents by which food particles are brought to the mouth, lying in a depression at the front end of the body. The *mouth*

opens into a mouth-cavity and this again into a muscular pharynx, which is continued by a short gullet into a wide stomach, this narrowing into an intestine which opens to the exterior on the upper surface of the body. Special interest attaches to the *pharynx*, usually known as the mastax, for the lining of this is thickened into a complicated set of hard pieces which work upon one another to crush the food. The transparency of the animal permits this process to be clearly seen, and it presents a curious and interesting spectacle, reminding one of the gastric mill in a lobster or the gizzard of a bird. The last section of the intestine is a *cloaca*, into which opens a thin-walled bladder (contractile vesicle) receiving nitrogenous waste matter from a couple of branched excretory tubes, which in some respects resemble the corresponding structures of the unsegmented worms. There are no specialized organs of circulation, these being represented simply by a fluid-containing body-cavity. *Respiration* takes place by the general surface of the body, as is very commonly the case with minute animals of all grades. The *nervous system* consists of a comparatively large brain, placed in the front part of the body above the mouth. A red *eye-spot* is imbedded in its upper surface, and it is also connected with a stiff *dorsal tentacle* (calcar) which ends in a bunch of stiff hairs and is probably an organ of touch.

Rotifers differ from one another in many respects. The general outline of the body varies largely, and the wheel-organ in particular may be very variously shaped. Sometimes the cuticle is thickened into a firm protecting carapace. Many members of the group are fixed, and in this case a cement-gland opens on the tip of the tail. Such forms often live in a cup or "house" of various nature. Some of these will be described later on, when the defences of animals are dealt with in detail.

MOSS-POLYPES AND LAMP-SHELLS (Molluscoida)

Considerable doubt attaches to the affinities of the two aquatic groups here associated together for convenience sake. They were originally included in the Mollusca. Milne-Edwards established "Molluscoidea" for Moss-Polypes and Tunicates, to which Huxley added Lamp-Shells. When, however, it was proved beyond doubt that the last group should without doubt be asso-

ciated with the Vertebrata (pp. 297–300), the term Molluscoida gradually fell into disuse, and the Moss-Polypes and Lamp-Shells were cut adrift. There is good reason for thinking that they are distantly related to the segmented worms, but their relationships to that group and to one another are very obscure. Perhaps the simplest plan will be to retain the old division Molluscoida for their reception, provided the derivation of the word (=mollusc-like) be ignored. As Huxley himself has remarked, it is often necessary to retain terms, the derivations of which have reference to obsolete views. The two included classes —1. Moss-Polypes (Polyzoa) and 2. Lamp-Shells (Brachiopoda)—are best considered separately.

Class I.—MOSS-POLYPES (Polyzoa)

These are small aquatic animals which are for the most part inhabitants of the sea, though some of them are found in fresh water. They present a peculiarity which so far we have only met with in some Tunicates (p. 300), *i.e.* they are *colonial.* From the egg a free-swimming embryo is hatched, which after a time becomes fixed and founds a colony by means of budding, in a way suggestive of what takes place in plants. The shape of the colony naturally depends upon the manner in which the buds arise, and it may be compact, flattened, or branched in a more or less elaborate way. There is a firm external skeleton for the support of the colony, sometimes of gelatinous nature, but more frequently of horny or calcareous consistency. Each member of the community (zooid) is lodged in a special depression or cup, and within the protective investment the bodies of the different zooids are connected together. The Polyzoa are among those animals included in the old group of "zoophytes" (Gk. *zōŏn*, an animal; *phyto*, a plant), so named from the exploded idea that they partook of the nature both of plants and animals, a notion largely due to the fixed nature and plant-like appearance of many kinds. Even yet some of them are popularly confounded with sea-weeds, and of such one of the most abundant is the Sea-Mat (*Flustra*) (fig. 269), the flattened branching skeletons of which are among the common objects thrown up on the shore by the action of the waves. Examination of one of these with a lens reveals the presence of innumerable closely-packed little cups,

the homes of the constituent zooids. Another common form is the Lace-Coralline (*Membranipora*), seen at low tide as a delicate lace-like encrustation upon the large brown sea-weeds.

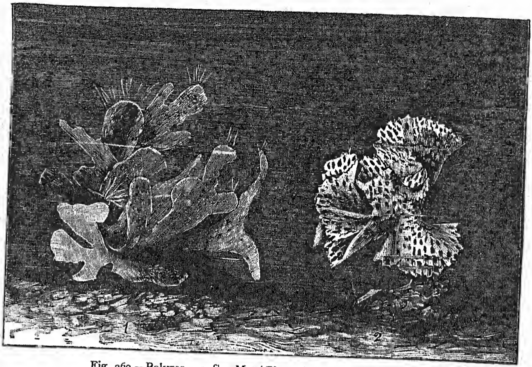


Fig. 269.—Polyzoa. 1, Sea-Mat (*Flustra*); 2, Sea-Net (*Retepora*)

The structure of the group is most conveniently studied in one of the fresh-water Polyzoa, the *Plume Coralline* (*Plumatella repens*) (fig. 270), the branched creeping colonies of which are

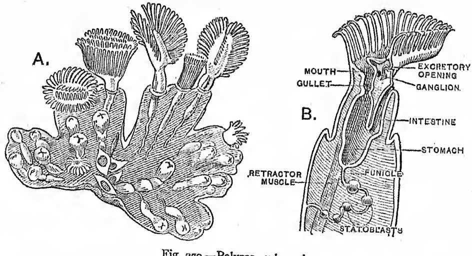


Fig. 270.—Polyzoa, enlarged

A, Small colony of *Lophopus crystallinus*, showing some individuals fully extended, and others in different states of retraction. B, Diagram of a single individual of *Plumatella*, cut through centre of body.

found creeping upon stones and other objects. The *skeleton* is horny, and from the tip of each branch a zooid can be protruded, the free end bearing the *mouth* surrounded by a double crown

of ciliated *tentacles* in the form of a double horse-shoe, within the concavity of which is the external opening of the intestine. This protrusible part of the body is drawn back or introverted by a retractor muscle at the approach of danger, reminding one of the arrangement which obtains in Sipunculus (p. 433), a further resemblance to which animal is found in the approximation of the two openings of the gut, an obvious convenience in a tube-inhabiting animal. Within the translucent body the U-shaped *food-tube* can be clearly seen, consisting of gullet, stomach, and intestine. There are two small excretory tubes opening near the tentacular crown. The *nervous system* consists of a nerve-ring closely surrounding the beginning of the gullet, and thickened on the side next the intestine into a bilobed brain- or cerebral ganglion. The stomach is connected with the body-wall by a fibrous cord (*funicle*) in which are developed buds known as *statoblasts*. In winter the colony dies down, to be replaced in the following spring by fresh colonies to which these buds give rise.

Another very beautiful fresh-water form, the transparency of which makes it an attractive object under the microscope, is *Lophopus crystallinus* (fig. 270), in which the skeleton is gelatinous, and the entire colony, instead of being fixed, is able to creep slowly along the surface of water-plants.

Class II.—LAMP-SHELLS (Brachiopoda)

These are exclusively marine forms, including only about 120 recent species, though their area of distribution (which includes the British seas) is extremely wide. In some of the geological periods, however, they were extremely abundant, but have gradually declined in importance from very early times.

The most striking characteristic is found in the presence of a *bivalve shell*, which for a long time caused them to be confounded with bivalve Molluscs (pp. 328–338). Taking a typical *Lamp-Shell* (*Waldheimia* or *Terebratula*) (fig. 271) as an illustration, we shall find many well-marked differences from the members of the last-named group. To begin with, the two valves are not right and left, but upper and lower, and they are of unequal size, the upper being the smaller. In side view the shell resembles

in outline an ancient lamp, a fact which has given the popular name to the class. The projecting beak of the lower valve is perforated by a rounded hole from which projects a cylindrical stalk by which the animal is attached, and which occupies the same relative position as the wick of the imaginary lamp. The fixed sedentary habit of this and most other forms is another point of contrast with the bulk of bivalve molluscs, which possess a marked power of locomotion. We shall further find that either valve is bilaterally symmetrical, which is not the case with a shell of cockle, mussel, or the like, while the two valves of such a mollusc are typically equal in size. There are also great differences in the minute structure of the shell.

Upon opening the shell of a Waldheimia, the animal will be found to occupy but a very small proportion of the space within, but there are two large coiled "arms", one on either side of the mouth, fringed with a double set of *tentacles* and suggesting the tentacular crown of Plumatella, if one supposes the halves of this to be much elongated and coiled up. The so-called arms are supported by a curved loop, shaped like a carriage-spring and projecting from the upper valve. A mantle-lobe lines either shell.

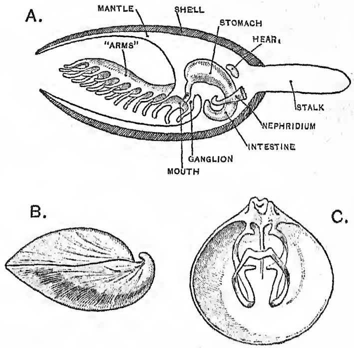


Fig. 271.—Lamp-Shell (*Waldheimia*)

A, Diagram of structure; body cut through centre. B, Shell, seen from left side. C, Interior of dorsal valve, to show "carriage-spring" support for arms.

In a bivalve mollusc the two halves of the shell are drawn together by adductor muscles and opened by an elastic ligament (p. 330). In a Lamp-Shell both processes are effected by muscles, and the hinge along which movements take place runs transversely and is placed close to the beak. The *gut* is a bent tube placed in the middle plane and consisting of gullet, stomach, and intestine, the last ending blindly. A good-sized digestive

gland opens into the stomach. The *excretory organs* are in the form of a pair of funnel-shaped tubes, which, like the nephridia of a segmented worm (p. 425), place a spacious body-cavity in communication with the exterior. The *central nervous system* essentially consists of a ring surrounding the gullet, and thickened above into brain- and below into other ganglia. (The upper part of the ring is not shown in fig. 271, A.)

CHAPTER X

STRUCTURE AND CLASSIFICATION OF FLAT-WORMS (PLATYHELMIA) AND THREAD-WORMS (NEMATHELMIA)

FLAT-WORMS (PLATYHELMIA)

The animals included in this phylum are unsegmented worm-like creatures which in most cases are markedly flattened from above downwards, hence the name of the group. They are divided into three classes:—1. Tape-Worms (Cestoda); 2. Flukes (Trematoda); 3. Planarian Worms (Turbellaria).

CLASS I.—TAPE-WORMS (CESTODA)

Tape-Worms are all internal parasites, and in the adult stage are almost without exception inhabitants of the food-tube in various Vertebrate animals, from Man downwards. The structure has undergone profound modification as a result of the parasitic habit, and the life-history is often complicated for the same reason. Details must be deferred till the phenomenon of parasitism is fully discussed, it being sufficient for the present purpose to briefly consider an average example of the group, the *Common Tape-Worm* (*Tænia solium*) (fig. 272), the adult stage of which is found in the human intestine. The long flattened whitish body has earned the name of "tape"-worm for the animal, which may be as much as 3 yards in length. It consists of a very small *head* and *neck* followed by the *trunk*, which gets broader and broader as we pass back to the hinder end, and is divided into a very large number of *joints*, which must not be mistaken for true segments such as have been described for annelids. It is indeed doubtful whether a tape-worm should be regarded as a single individual. An alternative view is that the head and neck together represent what may be called the primary individual, from which a long series of secondary individuals, the joints, has been originated.

Close examination of the minute *head* by means of a lens

shows that at its front end there is a double circlet of horny *hooks*, behind which four large *suckers* are arranged at equal distances. By means of these hooks and suckers the head is attached to the mucous membrane lining the intestine of the host. Such organs of attachment are common among parasites, and another example is given further on in the case of the Thorn-headed Worm (p. 449). No trace of a mouth can be seen, and indeed *digestive organs* are entirely absent, for the parasite lives at the expense of its host, absorbing through the general surface of its body the digested food with which, in the small intestine, it is surrounded. Nor are there any special *circulatory* or *respiratory organs.* The *excretory organs* are well developed and quite unlike the paired nephridia of segmented worms. They consist essentially of a narrow tube on each side, running not far from the edge of the body, and connected with elaborate branching canals which ramify in the soft substance filling up the spaces between all the internal organs. The *nervous system* is feebly developed, and its central parts consist of a longitudinal cord on either side, these being connected in the head by a transverse band, which may be regarded as equivalent to a pair of brain-ganglia.

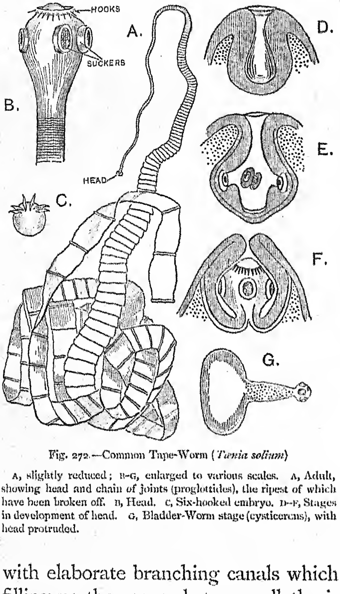


Fig. 272.—Common Tape-Worm (*Tænia solium*)

A, slightly reduced; B–G, enlarged to various scales. A, Adult, showing head and chain of joints (proglottides), the ripest of which have been broken off. B, Head. C, Six-hooked embryo. D–F, Stages in development of head. G, Bladder-Worm stage (cysticercus), with head protruded.

The *joints* which make up the trunk are largely filled with *egg-producing organs*, and, at the hind-end, joints full of ripe eggs are from time to time detached, passing out of the body of the host to the exterior. If any of these joints are devoured by a pig, the eggs hatch out in its stomach and the spherical embryos,

each of which is provided with three pairs of hooks, bore their way into the blood-vessels and are carried to the muscles, where they pass into a quiescent stage (pork "measles"). If a pig so infested is slaughtered, and some of the "measly" pork eaten in an imperfectly cooked condition by a human being, the life-history of the parasite is continued a step further, for the "measles" develop in the intestine of the new host into adult tape-worms.

CLASS II.—FLUKES (TREMATODA)

Flukes, like Tape-Worms, are parasitic forms, but they present a wider range in the nature of their parasitism, some being found attached to the exterior of other animals, while some live within various organs of the host. Here again it will, for the present, suffice to describe a single member of the group, and the type which is most commonly taken as a sample is the *Liver-Fluke* (*Fasciola hepatica*) (fig. 273), a much-dreaded agricultural pest which gives rise to the disease of sheep known as "liver rot".

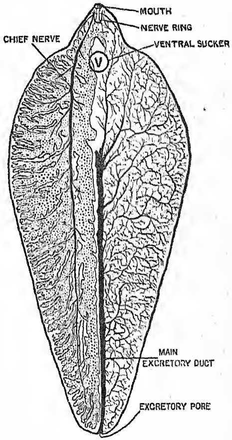


Fig. 273.—Liver-Fluke (*Fasciola hepatica*), diagrammatic

The adult Liver-Fluke is found often in large numbers in the liver of the sheep, or, in some cases, of other animals, among which Man must be included. The body is leaf-shaped and about an inch long. At the front end there is a conical projection on the tip of which is a *sucker* surrounding the opening of the mouth. There is a second sucker placed farther back on the under surface of the body, and the excretory organs open by a minute pore at the tip of the hinder end. The animal is covered by a thick *cuticle* beset with minute backwardly-directed spines, which facilitate an onward wriggling through the substance of the diseased liver, which gradually becomes more and more degenerated and broken down, till at last, in bad cases, the sheep dies.

The *internal structure* of the Fluke is extremely complex, and only a few of the more salient features can be mentioned. The *body-wall* consists of the cuticle with underlying epidermis and muscular layers, within which the spaces between the various organs is filled up by a soft packing material, much as in a tape-worm. Here, however, though special *circulatory* and *respiratory organs* are absent, the *digestive system* is well developed, for the surrounding food, consisting of blood and broken-down liver substance, requires to be digested. The mouth leads into a muscular pharynx, acting as a suction-pump, this into an extremely short gullet, and this again into a forked intestine, the halves of which are much branched and end blindly. The *excretory organs* are much of the same kind as in the Tape-Worm, and the *nervous system* is not much better developed. It consists of a ring round the front part of the gut, thickened above into ill-defined cerebral ganglia, and giving off a number of nerves, of which the most important take a backward direction.

The *life-history* is more complex than that of the Tape-Worm, and of a remarkable character, including a number of stages. The ripe *eggs* produced by the adult Fluke may be taken as the point of departure. These pass down into the intestine of the sheep and thence to the exterior. If they happen to fall into water or on to damp grass, and fluke-disease is commonest in wet fields, an elongated *ciliated embryo* hatches out from each of them. This swims actively about for some time, and if it happens to come across a certain small water-snail (*Limnæa truncatula*), further stages in its life-history become possible. The larva makes its way into the lung of the snail and becomes a shapeless bag (*sporocyst*) within which are developed a number of cylindrical rediæ, constituting the next stage. The *redia* makes its way out of the sporocyst and travels to the liver of the snail, upon which it preys. The last stage in the life-history is the tadpole-like *cercaria*, which is really an immature fluke, and this is produced within the redia much as that took origin within the sporocyst. The cercaria leaves the snail, and, swimming through the water by means of its tail, reaches a piece of grass or some other plant, to which it becomes attached. The tail is lost and the body becomes invested in a firm limy coat or cyst. If now a sheep should happen to swallow one of these encysted forms, the limy covering is dissolved by the action of the gastric juice, and the young fluke, escaping,

passes on into the small intestine, whence it travels up the bile-duct into the liver, there becoming adult.

CLASS III.—PLANARIAN WORMS (TURBELLARIA)

These are widely-distributed flat-worms, differing from the members of the two preceding classes in being as a rule free-living, though a few are parasitic. All are carnivorous. Planarians are found abundantly in the shallower parts of the sea and in fresh water, while others are terrestrial, and are to be seen on damp earth and vegetation. One of the commonest British species is a fresh-water form, *Planaria lactea* (fig. 274). It is a flattened whitish creature of elongated oval shape, and an inch or less in length, which may be found gliding along over water-plants and stones. These movements are effected by a uniform covering of *cilia* with which the soft skin is clothed, and the presence of which constitutes one of the important differences from the Tape-Worms and Flukes. The ciliary action sets up minute currents and whirlpools in the surrounding water, which can easily be seen with a lens, and have given rise to the name Turbellaria, from the Latin *turbellæ*, a word vulgarly employed to denote the bustling of a crowd.

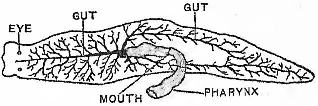


Fig. 274.—*Planaria lactea* (enlarged), with pharynx protruded to exterior

The front end of the body is comparatively broad, while the hind end is pointed. Upon the under side of the body, nearer the hind than the front end, is situated the *mouth*, which leads into a muscular *pharynx* continuous with a three-branched *intestine*, of which one section is directed forwards and the others backwards, while all three are beset with numerous branches that end blindly, reminding one of the condition of the digestive organs in a Liver-Fluke (p. 444). When the animal is in pursuit of prey, the pharynx is protruded from the mouth and used as an organ of capture, the food being taken directly into it, so, paradoxical as it seems, the mouth is not used as a mouth. As in Flukes and Tape-Worms there are muscular layers beneath the skin, and the spaces between the complex internal organs are filled up with packing material. As, too, in those forms there are no *circulatory* or *respiratory organs*, and the *excretory structures* are much of the same kind. The

central nervous system consists of a pair of brain-ganglia in the front part of the body, giving off various nerves, of which the two longest take a backward course. Upon the upper side of the head region are two simple *eyes*, each of which is provided with a lens and supplied by a special optic nerve.

The *Land Planarians* largely agree with the preceding in structure, but are much more worm-like in appearance, though equally unsegmented. Some of the tropical forms attain a large size (up to 18 inches when extended), and are brilliantly marked with longitudinal streaks of colour, but our few native species are dull in colour and insignificant in size. An example is *Rhynchodemus terrestris*, which is under an inch in length, whitish in colour below and dark-grey above.

The commonest example of the *marine Turbellaria* native to Britain is probably *Leptoplana tremellaris* (fig. 275), which is frequently to be found adhering to the under surface of stones between tide-marks. It belongs to a group which is exclusively marine, and differs in a number of important particulars from *Planaria lactea.* The flattened oval body is rounded at either end but considerably broader in front. Not only is the animal able to progress in the gliding manner already described, but it can also swim with considerable rapidity by flapping the sides of the body up and down. It then looks curiously like a minute Skate. The *mouth* is situated about the middle of the under surface, and the *pharynx*, when protruded from it, resembles a wide funnel with plaited sides. This region of the gut leads into an elongated oval *stomach* from which branching, blindly-ending tubes radiate in all directions. The bilobed *brain* is situated fairly far back, and gives origin to a number of radiating nerves. There are four groups of simple *eyes* situated on the upper side of the body, in the neighbourhood of the brain.

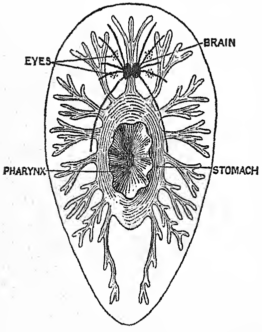


Fig. 275.—*Leptoplana tremellaris* (enlarged), as seen from under surface, with pharynx protruded to exterior

Certain Turbellarians belonging to the same group as the

species just described are brightly coloured, and some of them attain a large size, one recorded specimen being six inches long and four broad.

Speaking generally, the class of Turbellaria is one of extreme interest, for it contains the simplest animals exhibiting bilateral symmetry, and this is obviously associated with the creeping habit (p. 22).

THREAD-WORMS (NEMATHELMIA)

This phylum comprises an enormous number of unsegmented worm-like forms in which both ends of the body are usually pointed. The large majority of them are parasitic in the bodies of plants or animals, and various modifications in structure have taken place in consequence of this habit. A common and large type is the *Round-Worm*, one species of which (*Ascaris lumbricoides*) infests the human intestine, while a much larger species (*Ascaris megalocephala*) often abounds in the corresponding part of the horse.

The body of a Round-Worm (fig. 276), though cylindrical, exhibits bilateral symmetry, but not in so marked a manner as in the higher worms. Jaws and paired appendages of all kinds are entirely absent. The *mouth* is placed at the front end, and is guarded by three flap-like *lips*, of which one is dorsal, while the interspace between the other two is in the mid-ventral line. Each side-lip bears a small papilla which probably has to do with touch, and two of these are to be found on the dorsal lip. The intestine opens on the under side, not far from the hinder end, which in the male is sharply bent round. Close examination shows the presence of four streaks running longitudinally along the body and corresponding to special modifications of the body-wall. Two of these streaks are the *lateral lines*, one on each side, and the others are *dorsal* and *ventral lines*, running in the median plane above and below respectively.

The *body-wall* resembles that of a Nereis (p. 426) in so far that it consists of external cuticle with underlying epidermis and muscle, but the differences in detail are very considerable. The cuticle is very firm and strong, probably serving to protect the animal from the digestive juices of its host, while the epidermis is indistinct and projects inwards to form the lateral and median

lines. As a result of this, the underlying muscle, which constitutes a sort of longitudinal layer, is broken up into four sections.

The *digestive organs* (fig. 276) consist of a narrow tube running straight through the body, beginning with a thick-walled gullet which passes into a thin-walled intestine. Between the gut and body-wall is a body-cavity containing fluid, but there is nothing else to which the name of circulatory system can be applied. There are no special breathing organs, and the *excretory organs* are quite unlike those of a segmented worm (p. 428), consisting as they do of a narrow tube running in each lateral line, and joining with its fellow in front to open by a minute pore on the under surface. The *nervous system* again is in many respects unlike that of a segmented worm (p. 428). It is closely connected with the skin, and its most conspicuous portions consist of a ring not far behind the mouth, from which nerves are given off both fore and aft. Those in front supply the lips, and of the others the largest are a dorsal and a ventral nerve which traverse respectively the dorsal and ventral lines.

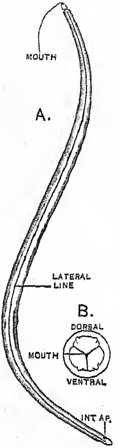


Fig. 276.—Round-Worm (*Ascaris*)

A, Side view; B, front end of body, much enlarged to show mouth and lips; INT. AP., intestinal aperture.

A common example of free-living Thread-Worms is the little Vinegar Eel (*Anguillula aceti*), common in paste and weak vinegar. Another curious creature, representing a group differing in many respects from the one containing Ascaris and Anguillula, is the Gordian-Worm (*Gordius*). This is a very slender black worm, often to be seen in pools or puddles, and the name has reference to the fact that a number of them may often be found twined together into a complicated tangle. In early life the Gordian-Worm is parasitic in an insect, leaving its host, however, when it becomes adult, and as large numbers do this about the same time, their appearance in public is somewhat sudden. Hence the rustic belief, once prevalent, that they have been rained down from the sky, a common explanation of the rapid appearance in any quantity of all sorts of small animals. Another curious popular idea, suggested by the appearance of the worms, is that they are horse-hairs into which the breath of life has mysteriously entered.

A small group, provisionally placed in the Thread-Worms, is that represented by a curious parasite the Thorn-headed Worm (*Echinorhynchus*), the front end of which is provided with a hook-studded projection, by means of which attachment to the lining of its host's intestine is effected. There are very many structural differences from such a typical form as the Round-Worm, the most remarkable being the absence of digestive organs, and it is more than doubtful whether the group should be included in the Thread-Worms at all. A typical species (*Echinorhynchus gigas*) lives, when adult, within the digestive organs of the pig, while its larval life is spent within the body of a Rose-Chafer or other related beetle.

CHAPTER XI

STRUCTURE AND CLASSIFICATION OF ECHINODERMS (ECHINODERMATA)

This is one of the most sharply-marked phyla in the animal kingdom, having specialized on very distinctive lines. Though considered after the flat-worms, it must not be imagined that it occupies a lower place in the scale. Indeed, as explained earlier (p. 11), it is impossible to place the various groups of animals in a linear series, each member of the series higher than the one next below it, and lower than the one next above it. But it is clearly necessary to describe the groups one after the other, just as if they actually formed such a series, and this is apt to give misleading ideas.

The phylum contains marine animals only, and probably the most familiar of these is the Common Star-Fish (*Uraster rubens*), found in abundance on many parts of our coast. It will serve very well as our illustrative example.

The body of a Star-Fish (fig. 277) is built on a plan quite different from those exhibited by the bilaterally symmetrical animals with which we have so far been concerned. As in a very large number of marine Invertebrates, there is a free-swimming larva, known in this case as a Bipinnaria, which is markedly bilateral. It is converted into the adult stage by a very complicated series of changes, constituting a true *metamorphosis*, one result of which is that the original bilateral symmetry becomes obscured, being replaced by a simpler kind of regularity to which the name of *radial symmetry* has been given, and which is well exemplified by the flower of a primrose, a cart-wheel, or a regular pentagon. In one kind of Star-Fish, indeed (*Goniaster*), the body is a pentagonal disc, but in the form selected for description, the corners of the pentagon have, so to speak, been drawn out so that a distinction can be drawn between a central *disc* and five radiating *arms*, which are continuations of it. In a Vertebrate, Arthropod,

or Worm, the body can be divided into corresponding halves in one way only, *i.e.* by a median plane which separates the right side from the left, but here this can be done in five different ways. Another way of putting it is to say that the body is regularly built up around a series of axes which radiate from a common central point. Any part or organ which is cut by one of these axes may be said to occupy a *radial* position, while *interradial* structures

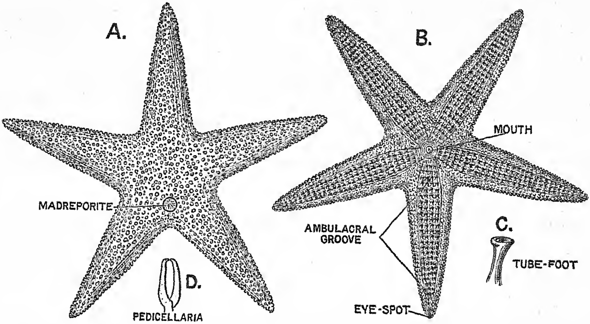


Fig. 277.—Common Star-Fish (*Uraster rubens*)
A and B, Upper and under surfaces, reduced; C and D, much enlarged.

fall between adjacent axes. There is, it is true, a distinction between upper and lower surfaces, as in vertebrates, &c., but it is by no means clear that we are justified in considering these to be truly dorsal and ventral.

Turning our attention to the pale under surface, we shall see, in its centre, the *mouth*, entirely devoid of jaws and placed in the middle of a soft area from which a deep groove runs along each arm to its tip. Occupying these five grooves are a large number of slender cylindrical structures which observation of a living star-fish shows to be used in locomotion, and which have consequently been termed *tube-feet*. Each groove has fancifully been termed an *ambulacrum*, because, together with its tube-feet, it suggested to the giver of the name a little pleasure grove or tree-lined avenue (Lat. *ambulacrum*). The tips of the arms are commonly seen to curl upwards, and each of them bears a reddish *eye-spot*.

The most conspicuous feature of the upper surface of the disc is found in the presence of a rounded plate in one of the interradial areas. The meandering grooves which mark its surface look like the markings upon certain corals (madrepores), and have suggested the name of madreporic plate or *madreporite.* As there is only one of these structures, the radial symmetry of the body is interfered with, and, strictly speaking, it is bilaterally symmetrical, the median plane passing through the plate and along one arm, which is generally considered to be the front or anterior one. So that the Star-Fish really presents bilateral symmetry masked by radial symmetry, so to speak. The minute aperture of the intestine is placed near the central point of the upper surface, but is not absolutely in the centre.

The Star-Fish is firm to the touch, owing to the presence of a well-developed system of hard *calcareous plates*, present in the deeper part of the skin, and which are best seen in a dried specimen. Those which support and strengthen the upper part of the body are united together into an irregular net-work, but in the neighbourhood of the ambulacra they are regular in shape and have a definite arrangement. Of these plates the most conspicuous are a double series of ambulacral ossicles united together so as to look, in the cross section of an arm, like an inverted V. The edges of the ambulacra are fringed with *spines*, and it is the presence of these in typical Echinoderms which has given the name to the phylum (Gk. *echinos*, a hedgehog; *derma*, skin). Spines, however, are much more numerous and conspicuous in the members of some of the other sorts of Echinoderm, notably in the Sea-Urchins, which is expressed in the name for "urchin", an old English word for a hedgehog. Among these spines, especially in the neighbourhood of the mouth, are some which have been peculiarly modified to form snapping jaw-like structures, known as *pedicellariæ.* One use of these is probably to assist in cleaning the surface of the animal.

Internal Structure (fig. 278).—Several points of interest are presented by the *digestive organs.* The *mouth* leads into a large *stomach* with folded walls, capable of being protruded outside of the body so as to engulf prey of comparatively large size. Star-fishes are extremely rapacious animals, and are among the worst enemies of the oyster. The stomach, after protrusion, is drawn back into the body by special muscles. It is continued into a

five-angled *pyloric sac*, and this into a short thin-walled *intestine*. The cavity of each arm is largely occupied by a pair of large saccular tubes which open into one of the corners of the pyloric sac, and secrete a digestive juice. The *circulatory organs* chiefly consist of an ill-developed blood-system devoid of heart, and of a spacious body-cavity. Special *respiratory organs* are evidently necessary in a creature furnished with a firm exo-skeleton, and in this case the function is discharged in part by delicate branched gills which can be protruded through the interstices of the calcareous net-work which strengthens the upper

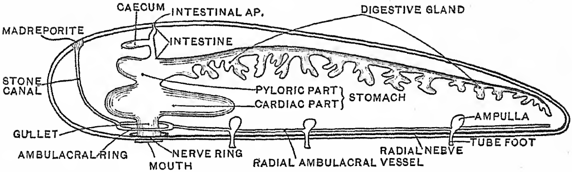


Fig. 278.—Common Star-Fish (*Uraster rubens*); cut through disc and one arm to show structure. Diagrammatic

surface. The tube-feet most likely help in breathing, and some of them in the neighbourhood of the mouth appear to be specially concerned with this function.

Great interest attaches to what is known as the *water-vascular system*, a set of organs to which the tube-feet belong, and which is quite unlike anything existing in other subdivisions of the animal kingdom. It consists of a tubular *ring* surrounding the beginning of the food-tube, and sending a *radial vessel* along each arm, just below the union of the two rows of ambulacral ossicles. The *tube-feet* are branches of the radial vessels, but they are also connected with little transparent bladders (ampullæ) placed within the cavities of the arms. The fluid filling the water-vascular system is largely sea-water, which is able to get in from the exterior by a *stone-canal* that runs from the madreporite to the central ring, the grooves in the former being perforated by numerous minute holes. The ampullæ, by their contraction, force fluid into the tube-feet, thus causing their protrusion. This method of working a set of locomotor organs is quite unlike anything we have so far met with, and it compensates for the comparative feebleness of the *muscular system*, correlated,

it would seem, with the marked development of a continuous exoskeleton, between the parts of which there are not, as in Arthropods, well-marked joints permitting of free movement.

The *nervous system* is of very primitive type, and arranged, like the other internal organs, in accordance with the radial symmetry of the animal. It is intimately connected with the skin, of which, in fact, it may simply be regarded as a thickening, and its best-marked portions consist of a *ring* round the mouth, and five *radial nerves*, one of which runs along each arm. But the entire body is invested in a nervous sheath, consisting of a delicate net-work lying in the deeper part of the skin. The chief *sense organs* are the tube-feet, which appear to be, among other things, tactile structures—indeed there is an odd tube-foot at the end of each arm which may definitely be called a tentacle,—and the *eye-spots* already noted.

What are known as "comet" forms of Star-Fish are not infrequently met with, *i.e.* specimens in which from one to four arms are smaller than the remainder. The small arms are new ones growing in place of others which have accidentally been lost. Lower animals often possess considerable powers of regenerating mutilated parts, and this is to a limited degree the case even among some of the Vertebrates.

Living Echinoderms are arranged in five classes:—1. Star-Fishes (Asteroidea); 2. Brittle-Stars (Ophiuroidea); 3. Sea-Urchins (Echinoidea); 4. Sea-Lilies and Feather-Stars (Crinoidea); Sea-Cucumbers (Holothuroidea).

Class I.—STAR-FISHES (Asteroidea)

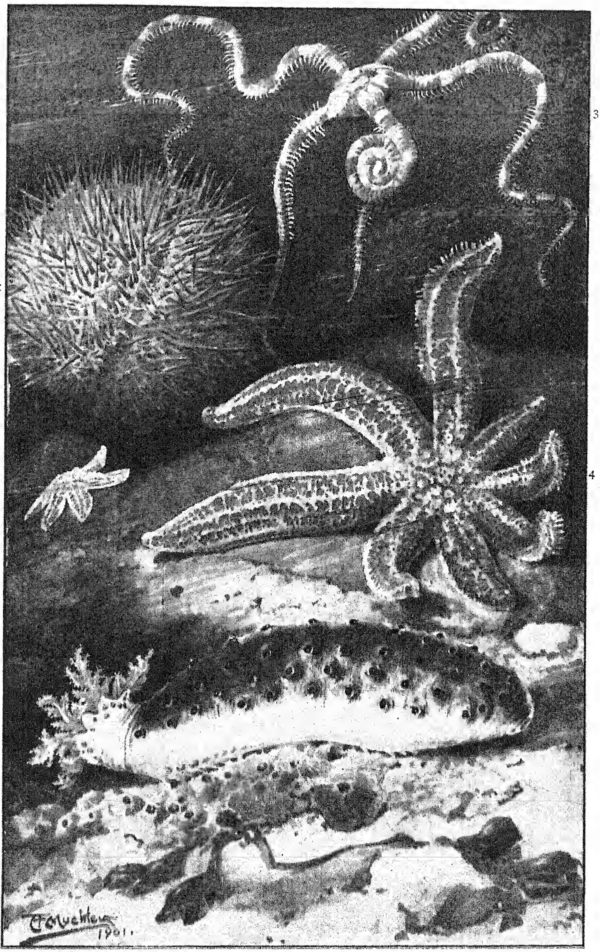
These conform in character to the described type in many at least of the particulars. They are found in all seas, and the majority are inhabitants of shallow water, though some, including the largest species, are found at considerable depths. There are generally five arms, but this is by no means a universal rule. A common British species, for instance, the Sun-Star (*Solaster papposus*), possesses no less than thirteen. The name has been given on account of its resemblance to the conventional symbol by which the sun is usually represented, *i.e.* a circle with a number of radiating lines.

ECHINODERMS

The animals here included constitute a well-marked group of marine animals, in which the body is typically star-shaped or spheroidal, or less commonly cylindrical. There is a more or less perfect calcareous skeleton developed in the skin, and part of it may consist of fixed or movable spines, hence the name of the group (Gk. *echinos*, a hedgehog; *derma*, skin: *i.e.* hedgehog-skinned). A peculiar system of tubes is present, containing sea-water and communicating with the exterior. In three of the constituent classes (star-fish, sea-urchins, and sea-cucumbers) part of this "water-vascular" system consists of sucker-like *tube-feet*, which are used for executing crawling movements.

Four common British forms are figured as types of the four classes now dominant, *i.e.* Star-fish (*Asteroidea*), Brittle Stars (*Ophiuroidea*), Sea-urchins (*Echinoidea*), and Sea-cucumbers (*Holothuroidea*).

1. Purple-tipped Sea-urchin (*Echinus miliaris*). Body covered by numerous spines attached by ball-and-socket joints to little knobs. ("*Urchin*" is an old name for the hedgehog.)
2. Black Sea-cucumber (*Holothuria nigra*). Leathery skin, in which scattered calcareous plates are embedded.
3. Brittle Star (*Ophiura*). Disc-like body with five flexible limb-like arms.
4. Common Star-fish (*Uraster rubens*). With five arms which are extensions of the central body. (The large specimen figured has more than the usual number of arms.)



1 2 3 4

ECHINODERMS

Class II.—BRITTLE-STARS (Ophiuroidea)

The members of this class, though to some extent they resemble ordinary star-fishes, and are by some naturalists included with them in a common section of the phylum, differ in a number of important particulars. There are a number of British species, of which one of the commonest (*Amphiura squamata*) is a little creature found on the under sides of stones near low-tide mark (fig. 279). It is at once evident that the five *arms* are sharply marked off from the *central disc*. They are indeed more of the nature of appendages, and are here the organs of locomotion, for which their extreme flexibility eminently fits them. Upon the under side of the disc, as in an ordinary star-fish, is situated the *mouth* in the form of a five-rayed slit. There are no ambulacral grooves, and the under side of each arm is covered by a regular series of flat plates, at the sides of which the *tube-feet* project. They are not, however, used as feet, but serve as organs of touch and respiration. There are no eye-spots on the tips of the arms. Turning to the upper surface, no trace of a madreporite can be seen; it is represented by one of the plates situated interradially on the under side. There is no intestinal opening at all. Each arm is covered by a single series of plates, and a similar series runs along each of its sides. The margins of the arms are spiny, but there are no pedicellariæ.

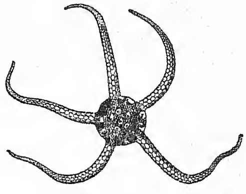


Fig. 279.—Brittle-Star (*Amphiura squamata*), seen from above. Enlarged

There are important differences as to internal structure between a brittle-star and an ordinary star-fish. The *mouth*, for example, is armed by a number of modified plates, and it leads into a spacious *stomach*, which bulges out into ten very short pouches. But there is no intestine and no digestive structures in the arms. Indeed each of these is traversed by a special series of ossicles, which have been called vertebral, because they are jointed together something like the successive vertebræ making up a backbone. Each of them is formed by the fusion of two ossicles, which are equivalent to a pair of the ambulacral ossicles of an ordinary

star-fish. The stomach is not capable of being protruded as in one of the ordinary Stars.

Class III.—SEA-URCHINS (Echinoidea)

Among the animals commonly brought up by the dredge in British seas, and sometimes thrown up on the beach by storms is the Edible Sea-Urchin (*Echinus esculentus*) (fig. 280), which,

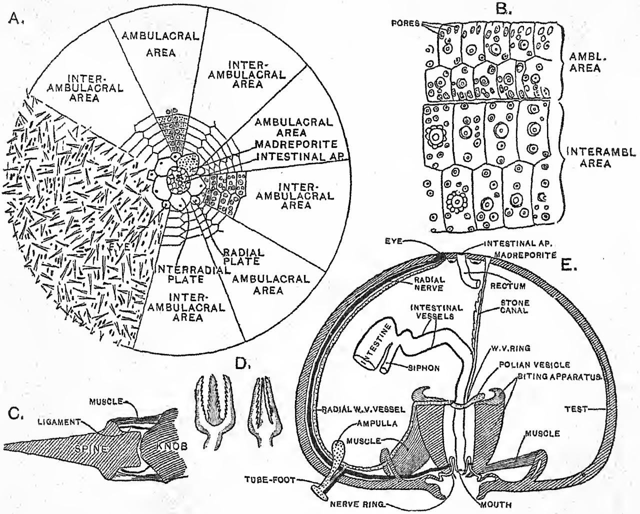


Fig. 280.—Edible Sea-Urchin (*Echinus esculentus*)

B, C, D, Enlarged to various scales. A, Diagram of upper surface, with most of spines removed. B, Plates of small part of an ambulacral and an interambulacral area, with spines removed. Pores for tube-feet and knobs for spines are shown. C, Diagrammatic section through spine and knob, to show mode of attachment. D, Pedicellariæ. E, Diagram of side-dissection, most of gut having been removed. W.V. is an abbreviation for "water vascular".

though it differs very much in appearance from a star-fish, is really constructed on much the same type. The spheroidal body suggests in appearance a curled-up hedgehog, whence, as previously explained, the name "sea-urchin", the appearance being due to the presence of an enormous number of *spines*, movably jointed to the underlying calcareous plates which, united firmly at their

edges, constitute a firm protective "test". The base of each spine is hollowed out into a cup which fits over a corresponding knob on the test, so that there is a ball-and-socket joint arrangement, and by means of special strands of muscle the spine can be moved in any direction. This is an adaptation to locomotion as well as to protection. Effective *tube-feet* are, however, present, and in a living sea-urchin these may be seen protruding between the spines, and if we compare the animal to a globe with upper and lower poles, their distribution is expressed by saying that they are arranged in five meridional bands.

As in a star-fish, the *mouth* is situated in the centre of the under surface, but in this case there are five pointed structures to be seen projecting from it, these being the tips of hard *jaws* shaped something like the front teeth of a rabbit. The opening of the intestine is placed almost in the middle of the upper surface.

On scraping away the spines, the characters of the *test* may be studied in detail, and it is found to be made up of twenty regularly-arranged sets of plates arranged in ten strips, which are broad in the middle but narrow at either end, like the "gores" which make up a balloon, or are sewn together to cover a child's cloth-covered ball. Two meridional rows of plates are united to make up each of these bands. Five of these differ in one important particular from the others which alternate with them, the distinction resting in the presence of a series of *pores* arranged in pairs, and placed near either edge of the band to which they belong, Each pair of these pores belongs to a tube-foot, which is thereby placed in communication with a radial water-vascular vessel, and with an ampulla (see p. 453), both of these being situated within the test. The presence of these pores enables us to distinguish between five *ambulacral areas*, bearing tube-feet, and five intervening *inter-ambulacral areas*. The former correspond to the radii about which the body is symmetrically built, and the others are consequently interradial. It may be useful to institute a comparison with the star-fish, taking for the purpose, not the common form, but the kind (*Goniaster*) shaped like a pentagonal disc. If we suppose the body of such a form to gradually swell so as to become spheroidal, while at the same time the original upper surface gets smaller and smaller, the lower surface (bearing the tube-feet), becoming correspondingly extended, the sea-urchin type will be produced. For the five ambulacral grooves will be converted into the five

ambulacral areas, and the regions between them into the five interambulacral areas.

There yet remain one or two other points to be noticed in the sea-urchin test. The plates at the upper pole, in the neighbourhood of the intestinal aperture, are somewhat specialized, and constitute an *apical disc*, the most important elements in which are ten plates, of which the five smaller ones are situated radially, and therefore correspond with the upper ends of the ambulacral areas. Each of them is called an "ocular", because it bears an eye-spot. The five interradial plates are somewhat larger, and one of them is modified into the *madreporite*, which has the same function as in an ordinary star-fish (see p. 452). Like that animal, too, the sea-urchin possesses those modified jaw-spines to which the name of *pedicellariæ* has been given, but in this case the jaws are three, and not two in number (fig. 281). Some possess poison-glands (fig. 281, right).

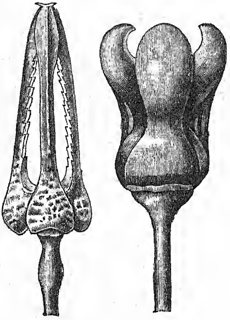


Fig. 281.—Three-jawed Pedicellariæ of Sea-Urchins; greatly enlarged

The *digestive organs* consist of gullet and intestine, the latter taking a spiral course, while the former traverses a complicated chewing apparatus fancifully called "Aristotle's lantern", and made up of the five jaws, together with many other hard parts. By means of special muscles the jaws can alternately be brought together and separated. As in the other groups of Echinoderms so far dealt with, there is a *blood system* of rather obscure nature, and the rest of the circulatory organs consist of a particularly spacious body-cavity in which the various internal organs are placed. *Breathing* is effected by the tube-feet, and also by ten branching *gills* placed in the neighbourhood of the mouth, and resembling the structures which project between the interstices of the skeleton in a star-fish (p. 453). This function is also possibly assisted by a narrow tube (siphon) running parallel to the gut and opening into it at either end. The *water-vascular system* is arranged on the same general plan as in a star-fish (p. 453), consisting of a ring round the gullet connected with the madreporite by a stone-canal,

and giving origin to five radial vessels of which the tube-feet are branches, these vessels, however, running within the test. The *nervous system*, too, is of the same general kind, but there are two nervous net-works, one outside the test and the other within it.

Sea-Urchins are grouped in two divisions: I. *Regular forms*, of which the just-described species is typical, and II. *Irregular forms*, in which there is a strongly-marked bilateral symmetry, and the body is often flattened, while the upper parts of the ambulacra are broadened out so as to collectively make up a flower-shaped figure, the tube-feet of which are definitely specialized into *gills*. These irregular forms again are divided into Shield-Urchins and Heart-Urchins.

Shield-Urchins are sometimes very much flattened, as the name implies, and though the mouth has the normal position, the aperture of the intestine is shifted back into an interradial position.

Heart-Urchins are distinguished by the shape under which the heart is conventionally represented, the notch of the heart being in front. The opening of the intestine is displaced to the edge of the disc, and the mouth, instead of being central, is shifted forwards. The Heart-Urchins are devoid of the special chewing apparatus known as "Aristotle's lantern". A common British species is the Purple Heart-Urchin (*Spatangus purpureus*).

Class IV.—SEA-LILIES AND FEATHER-STARS (Crinoidea)

This is a decadent group, once of great luxuriance, but of which the most typical modern representatives are rare, and confined to the very deep sea. Taking such a typical Sea-Lily, for example, as *Pentacrinus* (fig. 282), it may roughly be compared to a star-fish with branching arms placed on the top of a long stalk, and having its mouth surface turned upwards. A certain vague sort of resemblance to a flower upon its stem has suggested the name.

Examining Pentacrinus more closely, there will be seen a relatively small central disc, or *cup*, as it is usually termed, from which five arms project. These are of the nature of appendages, and begin almost at once to branch in a forking manner. Each branch bears a double series of short filaments termed *pinnules*, the name having reference to the arrangement seen in some plants,

e.g. in many ferns, where a central axis supports a row of leaflets on each side in a feather-like way. The *mouth* is in the centre of the upturned disc, and from it radiate five *ambulacral grooves*, corresponding to the similarly-named structures in a star-fish (p. 451). As the arms branch, so do these grooves, and their smallest subdivisions run along the pinnules. Projecting from each side of an ambulacral groove and its branches are a series of delicate pointed structures representing the tube-feet of a star-fish, but here no longer having anything to do with locomotion. The intestine opens near the mouth upon a projection situated in one of the interradial spaces. The under side of the cup is supported by regularly-arranged circlets of calcareous plates, some of which are comparable, it would appear, with the apical disc of a sea-urchin. There is, however, no madreporite. The under side of each arm, arm-branch, and pinnule is also supported by a series of hard parts, jointed together, however, so as to permit of a certain amount of movement. The stalk upon which the animal is supported is five-sided, and it is supported by a series of calcareous pieces, in the form of prisms

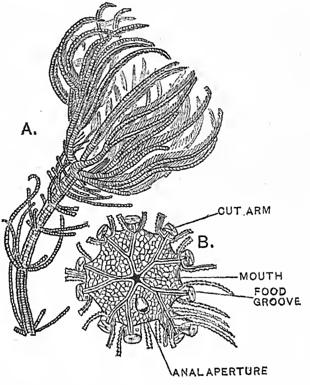


Fig. 282.—Sea-Lily (*Pentacrinus*)
A, Calyx and part of stalk (reduced). B, Upper side of calyx, with arms cut off.

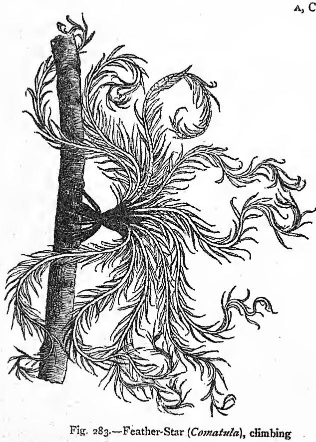


Fig. 283.—Feather-Star (*Comatula*), climbing

joined end to end. At regular intervals the stalk bears circlets of jointed filaments (*cirri*) which also are strengthened by a deposit of lime.

The *internal structure* is very complex, and it need only be said that the gut does not extend into the arms, and that apart from it the chief organs have the radial arrangement described for other types.

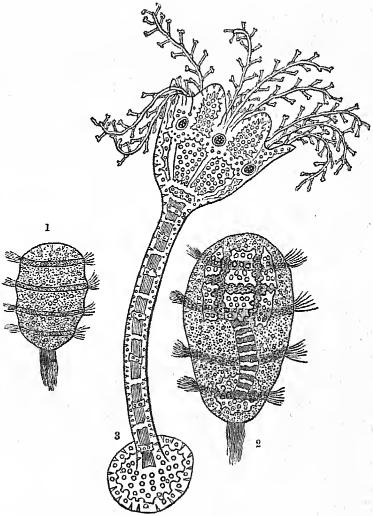


Fig. 284.—Stages in development of Feather-Star (*Comatula*), much enlarged. 3 is the stalked or pentacrinus stage

Although Sea-Lilies are distinctly scarce animals, the same can scarcely be said for the Feather-Stars, of which one kind (*Antedon* or *Comatula rosacea*) (fig. 283) is not uncommon in British seas. Its *life-history* is one of peculiar interest, for the eggs develop into a stalked *larva* which is found attached to sea-weed, and looks like a minute Sea-Lily (fig. 284). Later on, the stalk disappears and the animal takes to a free life, though it is possessed throughout its existence of a circlet of cirri, corresponding to the top circlet of those structures in a stalked form, and used to anchor the creature, and also in climbing. The life-history is interesting, chiefly because it is one of the best-known examples of a case where the development of the individual is a compressed presentment of the genealogy of the species. If the Feather-Star were the only known Crinoid there would be a strong presumption that its remote ancestors were stalked, and this conclusion is fully borne out by a study of recent and fossil forms.

Class V.—SEA-CUCUMBERS (Holothuroidea)

These are for the most part leathery elongated forms, some of which look uncommonly like cucumbers, a similarity which has suggested the name of the group. They are regarded by some authorities as representing most nearly of living animals the ancestral stock from which all Echinoderms must be supposed to have taken origin. This, however, is extremely doubtful; but as unfortunately the class, unlike the other ones included in the phylum, is but poorly provided with hard parts, fossil remains are infrequent, and throw but little light upon the question.

In a typical Holothurian (such as the genus *Cucumaria*) (fig. 285) the elongated body is somewhat angular, and the two openings of the digestive organs are at opposite ends of the body, the *mouth* being surrounded by a circlet of ten branching *tentacles*, which can be retracted. The *ambulacral areas* are marked by five double rows of *tube-feet* protruding along the side of the body. No trace of a madreporite can be discerned. The body-wall consists of skin and underlying muscles, the latter being as well developed here as they are scanty in those forms which have a well-developed exoskeleton. The *hard parts* of a Holothurian are comparatively insignificant, the most important of them making up a calcareous ring round the gullet; and there are, besides, minute calcareous spicules scattered through the skin.

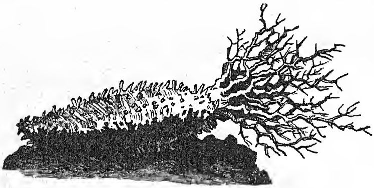


Fig. 285.—A Sea-Cucumber (*Cucumaria*), reduced

The *mouth*, as already stated, is placed in the middle of the crown of *tentacles*, and these are arranged in five pairs, one for each ambulacral area. One pair is smaller than the rest, and is used in shovelling food into the mouth. They correspond to the under surface of the body, which in some other members of the group is very sharply defined, though here the radial symmetry is not much interfered with. The mouth leads into a mouth-cavity, which opens into a gullet, and this again into a looped

intestine, which dilates near its termination into a section which is known as the *cloaca*, though it can scarcely be said to correspond to the similarly-named cavity found in many of the vertebrate animals (see pp. 69, 146, 200, 240, 261).

The *circulatory organs* consist, as in a star-fish or sea-urchin, of a blood system and a lymph system. The former is chiefly made up of a ring round the beginning of the gut, of five radial vessels, and of branches to the digestive and some of the other internal organs. The lymph system consists of the spacious body-cavity filled with fluid, in which float both colourless and red corpuscles, reminding us of the blood of a typical vertebrate (see p. 38).

Breathing is no doubt partly effected, as in other cases, by the tentacles and tube-feet, but there are also other structures which probably have to do with the same function, in the form of two large branching *respiratory trees* that open into the cloaca. The branches of these organs are beset with innumerable minute ciliated funnels, by which the body-cavity is placed in communication with the exterior. It is extremely likely that these trees also have to do with getting rid of the nitrogenous waste of the body, and if so, they are *excretory* as well as respiratory organs.

The *water-vascular system* is constructed on the same plan as in a star-fish. There is a ring round the beginning of the gut from which a radial vessel runs along each ambulacrum to give off the double row of tube-feet. Branches of these vessels supply the tentacles, which are to be regarded as much-modified tube-feet, and there is a stone-canal with a madreporite which, instead of opening to the exterior, hangs down into the body-cavity. In a very young Holothurian, the stone-canal opens directly to the exterior, as in a star-fish or sea-urchin, but this connection is lost in the typical forms, though there are some deep-sea species in which it persists throughout life.

The *nervous system* is of the type already described for other subdivisions of the class (p. 454). *Sense Organs* are chiefly represented by the tentacles and tube-feet, which no doubt have to do with the sense of touch.

Within the limits of the class there are numerous variations in many respects. Certain deep-sea forms present a well-marked bilateral symmetry, and the body is produced into pairs of projecting processes. In such forms, a well-marked flattened lower

surface upon which the animal creeps presents a sharp contrast with the curved upper surface. This is also the case with some of the species inhabiting much shallower water, and in these bilateral forms, three of the ambulacra are turned downwards, and bear tube-feet used in locomotion, while the other two face upwards, and their tube-feet are modified into pointed structures useful only as organs of breathing and touch. The tentacles also present a considerable variety in size and shape. Some common forms have the tube-feet irregularly scattered over the body instead of being arranged in rows, while in yet others the tube-feet, and even the radial branches of the water-vascular system, are absent altogether. This is the case, for example, in the genus *Synapta*, species of which are found in British seas. Here the translucent body is worm-like, and the small tentacles are feather-shaped, a further character of interest being found in the shape of the calcareous plates embedded in the skin, which are in the form of anchors with associated oval perforated plates (anchor plates). It also possesses ten minute *auditory sacs* in close connection with the nerve-ring.

CHAPTER X

STRUCTURE AND CLASSIFICATION OF ZOOPHYTES (CŒLENTERATA), SPONGES (PORIFERA), AND ANIMALCULES (PROTOZOA)

ZOOPHYTES (CŒLENTERATA)

The old expression "zoophyte" was applied to branching colonies of organisms regarding the animal nature of which doubt existed, and which were looked upon as being intermediate between animals and plants. Here were included the forms already briefly dealt with under the heading of Polyzoa (p. 436), but these are of much higher structure than the bulk of zoophytes, which may conveniently be grouped together under the phylum now to be considered. This embraces the Corals, Jelly-Fish, Sea-Anemones, and other creatures less familiar to the ordinary observer. As a simple and easily obtained type, it is customary to take the *Fresh-water Polype* (*Hydra*) (fig. 286), which is often found attached to pond-weeds, or sticking to the glass of a fresh-water aquarium. By leaving such an aquarium in a brightly-lit window for some time, one may often secure a supply of these animals, which collect on the side next the light. As they are not more than about $\frac{1}{4}$ of an inch long, the naked eye alone is not sufficient for their proper examination. Much can be made out with a simple lens, but a compound microscope is necessary to determine details. This is one of the numerous cases where important results are to be obtained by means of cutting thin slices with a razor, an operation which requires that the animal

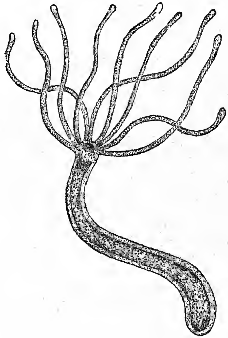


Fig. 286.—Green Hydra (*Hydra viridis*), enlarged

should be killed, stained, and imbedded in paraffin wax or some similar substance. Extremely delicate slices of known thickness can be cut by means of the instrument known as a *microtome*, in which a sharp razor is mechanically drawn across the imbedded specimen, this being held firmly by a suitable device. The slices, when prepared, have to be cleared from paraffin and mounted on a glass slide, in some transparent medium, such as glycerine or Canada balsam.

Specimens of Hydra are brown (*e.g. Hydra fusca*) or green (*Hydra viridis*) (fig. 286) according to the species, but in any case the form and structure are much the same. The colour of the green kind is particularly interesting, since it is due to the presence of a pigment (chlorophyll) which is characteristic of ordinary plants, and, as we shall see later, plays a leading part in their nutrition. The body of a fully-extended individual is a hollow cylinder closed at one end, the *foot*, by which attachment to a firm object is effected, while it is narrowed and open at the other, the aperture being the *mouth*. A circlet of long slender *tentacles* is situated quite close to the mouth, just where the body begins to narrow. The large internal *digestive cavity* has no other opening to the exterior. We find here a perfect example of the star-like or *radial symmetry* which is exemplified in a less complete manner by a star-fish or regular sea-urchin, and there is absolutely no trace of the bilateral symmetry so characteristic of higher forms (see p. 21). In other words, there is no distinction between front and back ends, right and left sides, or dorsal and ventral surfaces.

If a fully-extended Hydra be touched or shaken it will at once become retracted, its body shortening into a little rounded lump, while the tentacles become minute knobs. Such an arrangement is obviously of a protective character. When in an extended position the animal is on the look-out for prey, if such an expression may be used in the absence of visual organs. Its food consists of small aquatic animals such as Water-Fleas (see p. 422), which are much higher in the scale, and would at first sight appear to have every chance of escaping capture. This, however, is not the case, for if one of these active creatures happens to come into contact with one of the tentacles of the Hydra it stops dead as if paralysed, and is then by the help of the other tentacles drawn down to the dilatable mouth and passes out of view into

the digestive cavity. The sudden arrest of activity on the part of the unfortunate water-flea is brought about by means of minute "thread-cells" or "nettling-cells", which, as will be explained elsewhere, are poisoned weapons of considerable virulence. Numerous groups or "batteries" of these are present upon the tentacles, on which they confer a roughened appearance, and they are also present, though less abundantly, upon other parts of the body. *Nettling-cells* are very characteristic of the Cœlenterates, a fact which has been painfully brought home to many bathers in the case of some of the larger jelly-fish, while even the innocent-looking sea-anemones have been known to seriously inconvenience persons who happened to touch them. Even, therefore, if Hydra, like many of its brethren, were condemned to remain fixed in the same spot it would not necessarily be starved, but, as already hinted, it possesses considerable powers of *locomotion*. It can, for example, slowly shuffle along upon the attached end of the body, and can also execute looping movements by alternately attaching the two ends of its body to the surface of a stone or water-weed, reminding one of what happens in the case of a leech (p. 432) or a looper caterpillar (p. 364). Specimens may also be found floating freely in the water, mouth downwards, with the foot close to the surface and held in place by what is known as surface tension.

Structure of the Body (fig. 287).—Most of the external characters of Hydra have now been dealt with, and it remains to consider the minute structure of the body as determined by means of the microscope. Much can be learnt by examination of a thin cross-section, which may instructively be compared with a similar section through the body of an earth-worm. There is a central space corresponding to the digestive cavity, and outside this the body-wall, which is clearly made up of an outer layer and a much thicker inner layer, the two being separated by a thin membrane (supporting lamella). These two layers are respectively known as the *ectoderm* (Gk. *ektos*, outside; *derma*, a skin) and *endoderm* (Gk. *endon*, within; *derma*, a skin), and a double body-wall made up in this way is eminently characteristic of Cœlenterates and Sponges, especially in embryonic stages, on which account these two phyla are often grouped together as the "*Diploblastica*" (Gk. *diplous*, double; *blastos*, germ or bud). Turning now to the section of earth-worm, we see in the middle

a space corresponding to the digestive cavity or gut, which, however, is not bounded directly by the wall of the body but by a wall of its own separated by a considerable space, the *body-cavity*, from the body-wall. Hydra is absolutely devoid of a body-cavity in this sense. If we attempt a comparison between the two animals, the epidermis of the worm may be looked upon as *ectoderm*, and the innermost layer of the wall of the gut would appear to be equivalent to *endoderm*. But the greater part of body-wall and gut-wall in the worm, together making up what is called the middle layer or *mesoderm*, has no distinct representative in Hydra, unless, perhaps, it is represented in an inadequate manner by the thin membrane between ectoderm and endoderm. The presence of a distinct third layer coming between ectoderm and endoderm is characteristic of all the phyla above the Zoophytes, and this comes out very clearly and simply in embryo stages. Hence all these phyla are collectively grouped together as *Triploblastica*, *i.e.* three-layered animals, as contrasted with the two-layered forms or Diploblastica. The body-cavity is simply a split in the mesoderm, dividing it into an outer sheet lining the ectoderm and an inner sheet investing the endoderm.

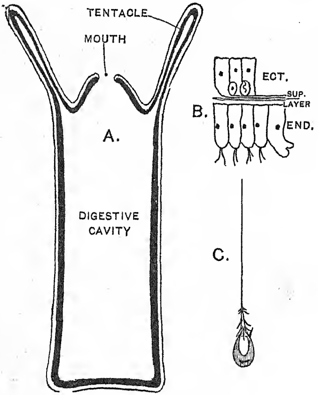


Fig. 287.—Diagrams, enlarged to various scales, illustrating the structure of Hydra

A, Longitudinal section: ectoderm left white, endoderm represented in black. B, Small part of longitudinal section through body-wall (the black dots are nuclei); ECT., three large cells and two packing cells are seen; SUP. LAYER, supporting layer or lamella; END., endoderm, showing four cells with flagella, and one with pseudopodia. C, A nettling-cell, with thread protruded—note barbs at the base of this, and the trigger hair on the right side; the protoplasm investing cell is shaded, and the nucleus represented in black.

Allusion has already been made to the fact that the body of a higher animal is made up of a number of different sorts of material having specific purposes and known as *tissues*, which are in effect the building materials from which the various organs are constructed. They are as follows:—1. *Epithelium*, consisting of

membranes which line internal cavities and cover the external surface, having in the latter case the name of epidermis; 2. *Supporting tissues*, such as bone, gristle (cartilage), and connective tissue which makes up tendons and ligaments, while it is also found as a sort of supporting framework in almost all parts of the body; 3. *Muscle*, constituting the flesh or meat, and also entering largely into the construction of the walls of various internal organs, such as heart and stomach; 4. *Nervous tissue*, constituting the essential part of the nervous system; and 5. *Blood* and *Lymph*, which must be looked upon as liquid tissues, serving as media of exchange. In a higher animal these various tissues are highly specialized so as to fit them for particular kinds of work; *e.g.*, muscle has as its province the bringing about of active movements. Indeed it may be said that animals are "high" or "low" in proportion as the division of physiological work is completely or incompletely carried out. In a high animal there is great complexity of structure associated with this perfect division of function, while exactly the reverse is true for a low animal. And in degenerate forms, such as the Ascidians (p. 297), animals derived from relatively complex ancestors have become simplified so as to suit them for simpler conditions of life. The loss of digestive organs by tape-worms (p. 441) is a further example of the principle.

Careful examination of any one kind of tissue shows that it is entirely or largely composed of structural units known as *cells*, comparable to the bricks and stones, &c., which make up the building materials of a house, if we pursue a comparison which has elsewhere been made use of. It is these cells that consist of the actual living substance, *protoplasm*, with which vital actions are associated. Each cell contains a particle of specially modified protoplasm known as the *nucleus*, which appears to be a regulative centre. These cells differ largely in shape according to the nature of the tissue. A simple case is that of lymph (p. 41), which consists of a clear fluid (plasma) in which are suspended innumerable irregular lymph corpuscles, which in this instance are the constituent cells. *Epithelium* (fig. 288) again consists of one or more layers of cells closely packed together and possessing various shapes in different cases. There is, for example, simple *scaly epithelium*, made up of flattened cells united by their edges and only one cell thick; this is comparable to a tessellated pave-

ment, each separate bit corresponding to a cell. The lining of heart and blood-vessels is of this nature. *Stratified scaly epithelium* resembles the preceding, but is several cells thick. Examples are to be found in the lining of the human mouth, and the epidermis of Frog. *Simple columnar epithelium* consists of prismatic cells packed together in a single layer, and is very characteristic of stomach and intestines. Other examples will be noted elsewhere. In many cases the surface cells of epithelium are provided

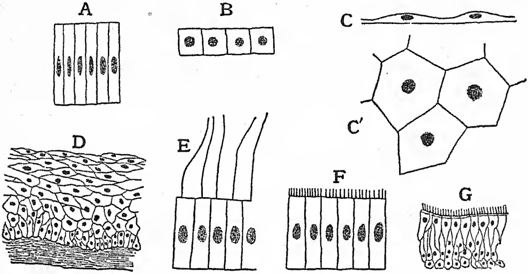


Fig. 288.—Different kinds of Epithelium, enlarged to various scales. All except C are in vertical section. Nuclei represented in black

A, Simple columnar; B, simple glandular; C, simple scaly; C′, simple scaly, surface view; D, stratified scaly; E, simple columnar, with flagella; F, simple columnar, with cilia; G, stratified, with cilia.

with numerous slender threads of protoplasm, cilia, which by their united action can set up currents. An individual *cilium* possesses the power of alternately bending and straightening itself. Various examples have already been given of the presence of such structures (pp. 49, 428, 445).

The *ectoderm* and *endoderm* of Hydra are to be regarded as tissues, but do not exhibit the high degree of specialization found in the phyla so far dealt with. They are more of the nature of epithelium than anything else, and this form of tissue is justly regarded as a comparatively primitive one. Beginning with the *ectoderm* (fig. 287), we find that the largest elements contained in this are what may be termed *tailed-cells*, since each of them is drawn out at its inner end into a fibre which appears to be of muscular nature. These tails all take a longitudinal direction, and collectively constitute a muscular layer by means of which the body can be shortened, supposing the fibres to contract or shorten

simultaneously. Filling up the spaces between these large cells are much smaller *packing-cells* with indistinct outlines, some of which become transformed into the *nettling-cells* already noticed, and force their way to the surface. Deep down in the ectoderm are also to be found scattered *nerve-cells* of star-shaped outline, collectively representing an extremely primitive form of nervous system.

The *endoderm cells* of Hydra are much larger than those of the ectoderm, and are provided with muscular tails running in this case transversely, so that collectively they make up a circular muscle layer, by the contraction of which the body can be extended. These cells also have digestive functions, and their free ends, which are directed towards the digestive cavity, can be protruded into lobes by which food particles are bodily engulfed, or, to speak more technically, ingested. Many of the cells are also provided with groups of protoplasmic filaments, which execute lashing movements by means of which the contents of the digestive cavity are kept circulating. These are called flagella (L. *flagellum*, a whip), and though they are in some respects allied to cilia, differ from them in the relative complexity of their movements, their larger size, and the fact that but a small number of them are to be found on the same cell. In the green Hydra, the endoderm cells contain numerous spheres in which the characteristic pigment is contained, while in other species similar spheres are present, differing, however, in the nature of the colouring matter.

From what has been said concerning Hydra it will be seen that in this animal there is but little specialization or division of the work of the body. As to *digestive organs*, the animal is little more than an animated stomach, food being procured by the action of the tentacles, and digested by the endoderm. *Circulatory organs* are entirely absent, and, indeed, they are not necessary, for the digested food can easily diffuse to all parts of the body. Waste products are similarly easily got rid of, and there are therefore no special organs of *respiration* or *excretion*. Both *nervous system* and *sense organs* are in a very undifferentiated condition, the latter being chiefly represented by sensitive "trigger hairs", with one of which each thread-cell is provided.

Development (fig. 289).—New Hydræ are produced either by a process of *budding* or from eggs. In the former case, a little knob

is seen to make its appearance on the body-wall, and, becoming gradually larger and larger, is shaped by degrees into a fresh individual, which ultimately becomes detached. This process goes on very vigorously in summer, and a Hydra may often be found bearing several mature buds, which, in their turn, are giving rise to a third generation. A temporary form of branching tree-like form is thus produced. Late in the summer, when external conditions as regards temperature and food become unfavourable, one or more rounded projections make their appearance near the foot, each of them containing an *egg*. After developing to a certain

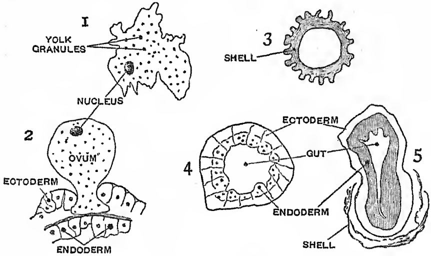


Fig. 289.—Development of Hydra, greatly magnified

1, Ovum. 2, Ovum, projecting from body-wall of parent. 3, Section through young embryo, to show protective egg-shell. 4, Cross-section of older stage. 5, Longitudinal section through embryo after rupture of egg-shell.

extent, the egg surrounds itself with a firm horny coating, serving as an efficient protection, and, invested in this, falls from the parent animal into the mud at the bottom of the pond or stream, where, in a dormant state, it is able to survive the winter, which is not usually the case with the Hydra itself. The development is completed in the following spring, when the egg-shell splits and the young animal makes its way out. In many groups of the animal kingdom, it is a common phenomenon for "winter eggs" of this kind to be produced, and the extinction of the species during the cold season is thereby prevented. A comparison may well be drawn with the seeds of higher plants, in which dormant embryos are contained that are able to resume growth with the advent of warmer weather.

An interesting property possessed by Hydra is its power of regenerating parts which have been injured or removed. To such

an extent is this carried, that if an individual is cut into several pieces, each of them becomes a fresh Hydra. Powers of this kind are common among lower animals, and, as might be expected, are greatest where the body is but little specialized, as in the case now under consideration. Another case was mentioned when dealing with the Star-Fish (p. 454). The absence of specialization in Hydra is not so great, however, as supposed by the older zoologists, who imagined that the animal was so little discomposed when turned inside out that it lived on with the functions of the layers reversed.

Zoophytes are conveniently divided into the following three classes:—1. Sea-Flowers (Anthozoa or Actinozoa); 2. Hydroids (Hydrozoa); and 3. Comb Jelly-Fish (Ctenophora),

Class I.—SEA-FLOWERS (Anthozoa or Actinozoa)

The brilliantly-coloured Sea-Anemones, Corals, Sea-Pens, and the like, which are grouped together in this class, justify its name (Gk. *anthos*, a flower; *zōŏn*, an animal), for, when expanded, they look not unlike chrysanthemums or double dahlias, to the individual florets of which the numerous tentacles bear a certain resemblance. Many of them are colonial, while others live singly, and of these we may take the common *Beadlet* (*Actinia mesembryanthemum*) as an example (compare fig. 290). It is abundant on rocks between tide-marks all round our coasts, looking, when expanded, like a scarlet flower, but shrinking to a rounded jelly-like mass when contracted. In the former condition, it may be compared to a short broad Hydra, but the mouth is in the centre of a wide disc, and is surrounded by several rows of comparatively short pointed tentacles. There are, however, important differences in structure. The *mouth* leads, not into a widely-continuous digestive cavity, but into a tubular *gullet*, which hangs down within the body, and ends abruptly below. This may be roughly represented by taking a piece of wide india-rubber tubing, and tucking in one end of it. The space between the lower end of the gullet and the base is called the *stomach*, and performs the function of a digestive organ. But this is not all, for running across in a radiating way from the body-wall to or towards the gullet are a large number of fleshy partitions, which divide the space external to gullet and stomach into a number of compartments. These partitions, or *mesenteries*, are, however, perforated above, so as to

put adjoining compartments into communication. The stomach, which is bounded by the thickened free edges of the septa, is of necessity continuous with the various compartments, except when digestion is going on, at which time the edges of the septa are brought close together, a digestive juice being poured out from them upon the food. These points will be made clear by examination of the accompanying diagram. It may further be noted that the sides of the gullet are furrowed by two grooves placed opposite to each, and this organ can be collapsed in such a way as to convert these grooves into narrow tubes, these being lined by long cilia, which work in such a way that a current of water runs inwards in one tube, and outwards in the other.

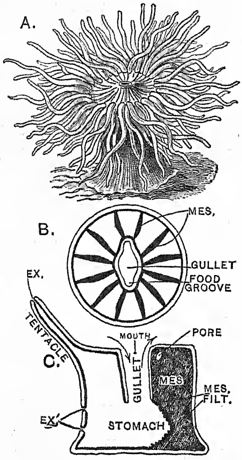


Fig. 290.—Sea-Anemone

A, External view of a Sea-Anemone (*Anemonia*). B, Diagrammatic cross-section; MES., mesenteries: only one of the two food-grooves is lettered. C, Diagrammatic longitudinal section, showing a mesentery (MES.), with mesenteric filaments (MES. FILT.) on the right, and one of the spaces between two mesenteries on the left; EX., EX'., excretory pores: the arrows indicate the course of currents into and out of the gullet along the food-grooves.

The *minute structure* corresponds in many ways to that of Hydra, there being ectoderm, endoderm, and a supporting lamella between them. Nettling-cells are abundantly present, but are more complex in pattern than those possessed by Hydra. There is further a greater amount of specialization, as seen especially in the muscular and nervous systems.

The Anthozoa include two orders:—1. Six-rayed Sea-Flowers (Hexactinia); and 2. Eight-rayed Sea-Flowers (Octactinia).

Order 1.—Six-rayed Sea-Flowers (Hexactinia)

These are distinguished by the fact that the tentacles are simple, while they and the mesenteries are usually arranged in multiples of six, and though this is often difficult to easily make out in the adult, it is clearly shown during the development. The Sea-Anemone just described is a good type of the order. Among

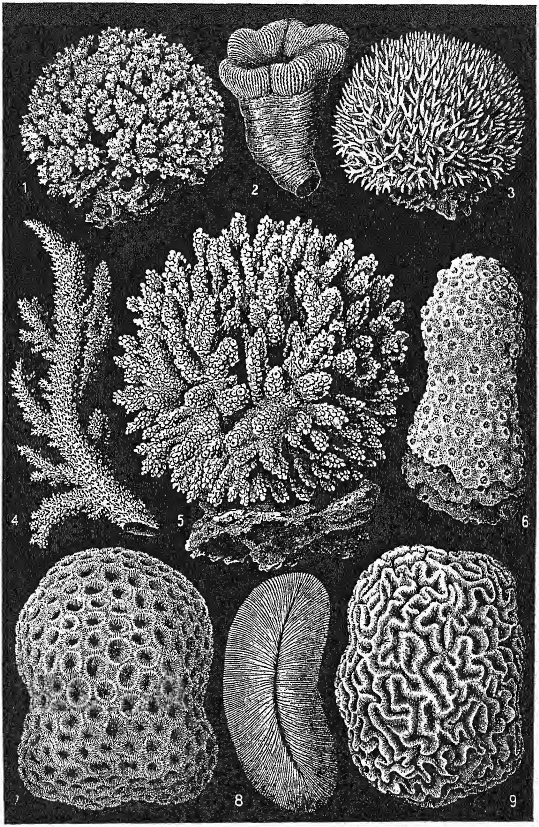


Fig. 291.—Skeletons of Arabian Corals, all reduced

1, Tuft-Coral (*Pocillopora favosa*); 2, Clove-Coral (*Trachyphyllia Geoffroyi*); 3, Antler-Coral (*Seriatopora subulata*); 4, Madrepore-Coral (*Madrepora laxa*); 5, Shrub-Coral (*Heteropora Hemprichii*); 6, Hedgehog-Coral (*Echinopora gemmacea*); 7, Sun-Coral (*Heliastræa Forskaliana*); 8, Mushroom-Coral (*Fungia scutaria*); 9, Brain-Coral (*Cœlaria labyrinthiformis*).

other British anemones may be mentioned: *Tealia crassicornis*, a large red form in which the outside of the body is studded with warts, to which fragments of sand or shells may be found adhering; and the brownish or greenish Opelet (*Anthea cereus*), which can only partially draw in its tentacles.

The majority of forms known as "corals" (fig. 291) are also members of the six-rayed order, and they include both simple and colonial species. Of the former may be mentioned a British species (*Caryophyllia Smithii*) found in the English Channel. In structure it is comparable to a sea-anemone, but a hard calcareous skeleton has been secreted by the ectoderm in the basal part of the animal. When the soft parts are removed this is seen to consist of a conical cup, from which calcareous plates project inward. A simple coral attaining a much larger size is the familiar Mushroom-Coral (*Fungia*), the flattened cup of which has some resemblance to the top of a mushroom, the gills being represented by the calcareous partitions or septa. Most corals, however, form colonies by budding (gemmation) or splitting (fission), and it is these which chiefly build up the coral-reefs so characteristic of the warmer parts of the ocean where the water is free from sand or mud. All sorts of different shapes may be assumed by the colonies, according to the species, some being encrusting or massive, while others branch in a tree-like way (fig. 291). The individual polypes may be separated by a larger or smaller interspace, so that their separate cups can be clearly made out, either imbedded in or else projecting from a *common skeleton* secreted by the common or colonial body (cœnosarc) which unites the different members together. In other cases the polypes are closely packed together, and it even happens in some cases that there is no proper division between them, it being only possible to determine the number of individuals by counting the mouths which are present.

Order 2.—Eight-rayed Sea-Flowers (Octactinia)

Although these forms agree in general plan of structure with corals and sea-anemones they also present striking differences, among which the most obvious are the possession of not more than eight feather-shaped tentacles and the same number of mesenteries. Nearly all the included species are colonial.

One of the commonest British members of the group is the organism to which the unpleasant name of *Dead-Man's Fingers* (*Alcyonium digitatum*) is applied, a name justified to some extent by the thick branches of the colony that look something like the swollen fingers of a clumsy hand (fig. 292). In a specimen cast up on the beach the individual polypes will have been drawn back into the fleshy substance of the colony, their position being indicated only by small depressions situated at a little distance from one another. Quite another appearance is presented by a living specimen with all the polypes protruded, these having a distinctly flower-like appearance, with eight feathery tentacles suggesting petals. As in an anemone, the mouth leads into a gullet, provided in this case, however (as also in some of the anemones), with but one ciliated groove, and united to the body-wall by only eight septa. The digestive cavities of the polypes are continuous with canals which traverse the common flesh. At first there appears to be no skeleton; but microscopic examination reveals the presence of numerous *calcareous spicules* of characteristic shape, scattered through the comparatively thick supporting layer which comes between the ectoderm and endoderm (see p. 474). There is reason to believe, however, that the spicules have been formed by the activity of ectodermic cells which have become detached from their own layer.

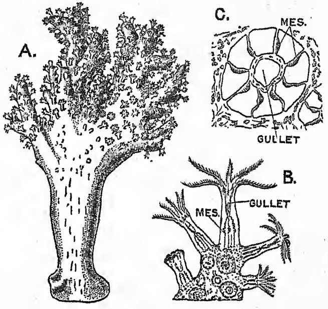


Fig. 292.—Dead-Man's Fingers (*Alcyonium*)

A, A colony, reduced. B, Tip of a branch, magnified, showing polypes in different stages of expansion and retraction; MES., a mesentery. C, Cross-section through body of a polype, magnified; MES., mesenteries (8 in all are present): note the single food-groove in lower side of gullet.

Another familiar example of the group is the *Organ-pipe Coral* (*Tubipora musica*), in a dried specimen of which may be seen numerous red tubes connected together by "platforms" of similar material at different levels. From these platforms new individuals grow up, and so the coral increases in breadth as it gets older. As in colonial corals generally the individuals are

limited to the surface-layer, while the deeper part of the mass is cut off by partitions and merely consists of dead material. In a living specimen of Tubipora the upper end of each tube is occupied by a polype of similar character to those found in Alcyonium, and adjacent members of the colony are connected by living matter which extends along the uppermost platforms. Microscopic examination of the skeleton shows that it is formed by the intimate union of innumerable minute spicules comparable in nature though not in shape to those of Dead-Man's Fingers.

Other examples are *Red Coral* (*Corallium rubrum*) (fig. 2), where there is a compact branching skeleton (composed of united spicules) covered by the common flesh (cœnosarc) of the colony from which the polypes project at intervals; *Sea-Pens* (*Pennatula*, &c.), where the colony is feather-shaped with a series of individuals on each side, while the axis is supported by a firm rod; and the *Sea-Mats* (*Gorgonia*, &c.), where the flat upright colony is variously branched and supported by a horny skeleton, which is covered by common flesh with polypes much as in the Red Coral.

Class II.—HYDROIDS (Hydrozoa)

The Fresh-water Polype, Hydra, has already been described as a simple type of this class (pp. 465–471), which is predominatingly marine. The apparent simplicity of Hydra, it should be noted, is in all probability the result of reduction, and a much better idea of the group is to be obtained by briefly considering one of those marine forms to which at different stages of the life-history the terms "hydroid zoophyte" and "medusa" are applied. The horny skeletons of zoophytes of this sort are cast up on the shore in abundance by storms, and some may be found growing near low-tide mark in rock-pools. They are often confused with sea-weeds in amateur collections, in which their branching skeletons are frequently to be found. A very common British genus is *Obelia* (fig. 293), for which there is no popular name. It will be remembered that in dealing with Hydra it was pointed out (p. 472) that during summer, when that animal is actively budding, two or three generations of individuals may be temporarily connected together. If these buds were to remain united, and the budding process were carried

further, a permanent branching colony would be the result. Obelia is a colony of this kind, and for its support some sort of skeleton is necessary, as is the case in the corals already described. Here, however, it is in the form of a horny investment, which covers the common body (cœnosarc) and expands at the tip of each branch into a little cup in which is lodged a hydra-like polype. There is, however, a further arrangement in the form of much larger cups (gonangia) within which are produced groups of special buds, the function of which is to produce eggs. When these buds are mature they are liberated in the form of small *jelly-fish* or *medusæ*, which lead an independent life for some time and possess active powers of movement. The jelly-like consistence in cases of the kind is due to the excessive de-

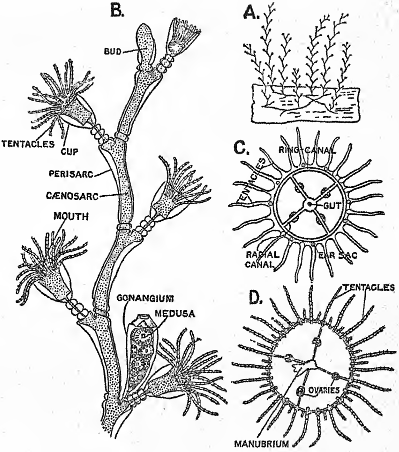


Fig. 293.—Fixed and Free-swimming Stages of a Hydroid Zoophyte (*Obelia*). A, Natural size; B–D, enlarged

A, A colony of the fixed (hydroid) stage, attached to a piece of sea-weed. B, End of a branch of same. C, Upper side, and D, under side of the free-swimming stage (jelly-fish or medusa).

velopment of the lamella between ectoderm and endoderm, which becomes thick and gelatinous, while cells from the two layers in question make their way into it. The little medusa may be compared to an umbrella with a very short handle (manubrium), and around its margin is a fringe of tentacles, eight of which have minute auditory vesicles at their bases, one to each. The *mouth* is situated at the end of the handle, and leads into a *stomach*, from which four tubes radiate to the edge of the umbrella, where they are continuous with a circular ring-canal. It may further be added that a little shelf or *velum* projects inwards from

the margin of the umbrella. The eggs give rise to hydra-like individuals, each of which develops a fresh colony by means of budding.

The Hydrozoa may conveniently be divided into two orders: 1. Budding Hydroids (Hydromedusæ); and 2. Splitting Hydroids (Scyphomedusæ).

Order 1.—Budding Hydroids (Hydromedusæ)

Obelia is a good typical example of the order, but in by no means all cases are egg-producing buds set free as medusæ, and a complete series of examples may be selected which range from that condition down to the state of things found in Hydra, where each egg is produced in a little swelling which has no resemblance whatever to a medusa. The intermediate stages are represented by cases where the egg-producing buds resemble medusæ but remain attached to the colony, and other cases where such buds may be compared to medusæ in which some of the typical features have been, as it were, suppressed.

Obelia is a type of one large division in which the fixed stage is distinguished by the possession of *cups* into which the individuals can be withdrawn, while if free-swimming jelly-fish are produced their sense organs are usually auditory vesicles. Other common British genera are *Sertularia* and *Plumularia.*

In another large group the investing skeleton ends abruptly at the base of each polype and does not expand into a cup, while the medusæ, if liberated as free-swimming individuals, usually possess eye-spots instead of auditory vesicles round the margin of the umbrella. *Tubularia* is a typical British genus, in which the polypes are comparatively large, and free-swimming medusæ are not developed. It is also customary to place Hydra in this group, as well as a very interesting marine genus, *Protohydra*, of somewhat similar character, though it has no tentacles, and is to be regarded as the simplest known member of the Hydrozoa.

Although most corals belong to the Anthozoa, there are a few cases of species belonging to the Hydrozoa which, instead of secreting a horny investment, develop a firm calcareous skeleton, and superficially resemble the true corals, though in reality sharply marked off from them by the structure of the soft parts. Representative genera are *Millepora* and *Stylaster*,

in which there are hydra-like *nutritive individuals*, without well-developed tentacles, and reduced *prehensile individuals* devoid of mouths, and looking like large tentacles richly provided with nettle-cells, and branched in the case of Millepora. Each nutritive polype is surrounded by a number of these modified individuals, the function of which is to secure food. There are also egg-producing members of the colony, comparable in function, though not in form, to the medusa-stage of Obelia.

It will have been gathered from the preceding that there is often a division of physiological work between the different members of a hydrozoan colony, just as in the complex body of a higher animal there is a similar division between the various tissues. This phenomenon is carried to an extreme in the free-swimming marine forms which are grouped together under the name of *Compound Jelly-Fish* (*Siphonophora*) (fig. 294). Each colony comprises individuals of the most various nature, and just as a hydroid zoophyte arises by the budding of a fixed hydra-like individual, so here we must suppose that buds of different kinds have been produced on a modified jelly-fish or medusa, in some cases upon the under side of the umbrella and in others upon the elongated mouth-stalk, which has been compared to the handle of the umbrella.

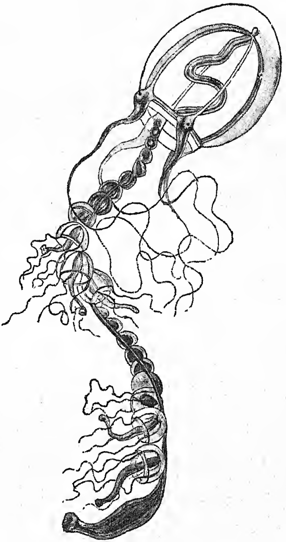


Fig. 294.—A Compound Jelly-Fish (*Sarsia*)

This may be regarded as a medusa (of which the large bell or umbrella is seen at upper end of figure) with a very long mouth-stalk (manubrium), on which smaller individuals are formed as buds.

Order 2.—Splitting Hydroids (Scyphomedusæ)

To this order belong the large jelly-fish which are often seen in great numbers in British seas during the warmer parts

of the year. The edge of the umbrella is lobed, the notches between the lobes sheltering peculiar sense organs formed by the modification of tentacles and covered by little lappets. Hence the term "covered-eyed medusæ" sometimes applied to these forms, to distinguish them from the "naked-eyed medusæ" of the preceding class, in which the marginal sense organs are not covered by such lappets. These terms, however, were not happily chosen, for it is only in certain cases that the sense organs have to do with sight. A negative characteristic of the jelly-fish included in this division is to be found in the absence of the true velum (see p. 479). The most typical members of the group present two stages in the life-history, as in Obelia (p. 480), *i.e.* (1) a fixed hydroid stage, and (2) the free-swimming medusa. The common British form *Aurelia* may be taken as an example (fig. 295). Here the fixed stage is what is called a *Hydra-tuba*, somewhat resembling a short, broad Hydra in shape, though internally it presents a difference in the presence of four longitudinal folds which project into the digestive cavity. Medusæ are developed from it, not by budding, but by a process of transverse splitting, and when the process is far advanced, the incipient medusæ may be compared to a pile of saucers. Sooner or later these become detached and grow into the mature jelly-fish, by which eggs are produced which complete the cycle of development by becoming hydra-tubæ.

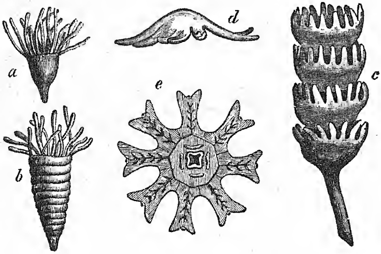


Fig. 295.—Development of Aurelia, enlarged

a, The fixed stage (hydra-tuba). *b* and *c*, Transverse splitting of *a* to form medusæ. *d* and *e*, Young medusa, seen from the side and from below.

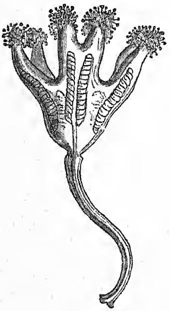


Fig. 296.—Lucernaria, enlarged

Some of the medusæ belonging to the order have no fixed stage, and in the case of certain other species (*Haliclystus*,

Lucernaria, &c.) there is, on the contrary, no medusa stage (fig. 296).

Class III.—COMB JELLY-FISH (Ctenophora)

These are small, transparent, free-swimming forms occurring in vast numbers in the open sea. When alive they are of extreme beauty. A common British genus, *Cydippe,* typically exhibits the features of the class (fig. 297).

Here the body may be compared in shape to a minute melon, with the *mouth-opening* at one pole and a complex *sense organ* at the other. Locomotion is brought about by eight longitudinal bands of little paddles which suggest the teeth of a comb. Each *paddle* is apparently made up of a number of cilia which have fused together. From each side of the body a long feathery *tentacle* can be protruded, which is used for the capture of food. These tentacles, when not in use, are drawn back into pouches. The *mouth* leads into a gullet, and that into a complex system of canals, which communicate with the exterior by two pores at the opposite end of the body. Nettling-cells are absent, but the tentacles are provided with glutinous adhesive cells by which particles of food are secured. There is no fixed stage in the life-history.

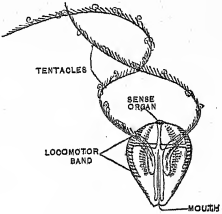


Fig. 297.—Cydippe

Among other genera may be mentioned *Venus's Girdle* (*Cestus*), in which the body is band-shaped and may be as much as a foot in length; and *Beroë,* a cap-shaped form devoid of tentacles. There are also two very interesting creeping genera (*Ctenoplana* and *Cœloplana*), which, as a result of their mode of life (see p. 23), present an approach to bilateral symmetry, and have been compared to some of the Turbellarian worms (p. 445), it even being suggested that the Turbellaria have been derived from ancestral forms closely related to the Ctenophores.

SPONGES (Porifera)

Sponges were long considered to be of vegetable nature, an idea that was only finally upset by the study of their minute structure. Except to a naturalist the word "sponge" merely suggests a bath-sponge, which is in reality the horny skeleton of a colonial species. To gain a clear idea of the structure of the group it is necessary to consider the simpler cases presented by some of the solitary forms. In the simplest of these the body is shaped like a cup or vase, fixed at one end and open at the other. It is tempting to draw a comparison with Hydra, or better with Protohydra (p. 480), which is simply a tube open at one end. Such a comparison, however, is beset with difficulties, for while in Protohydra the aperture is clearly a mouth through which food is introduced, it will be found by watching the living sponge that currents of water are constantly flowing out of the corresponding opening, here technically known as the *osculum* (L. for little mouth). And, further, the body-wall of the sponge is perforated by numerous small holes through which water-currents set into the central digestive cavity. These currents are the result of ciliary action, and by their means the animal is provided with the food and oxygen it requires, while the various products of waste are swept out to the exterior through the osculum. This mode of life is associated with the sedentary or fixed habit of sponges, which is the chief reason for the old mistake of considering these creatures of vegetable nature.

Microscopic examination shows that the thin body-wall of the simple sponge consists of an external ectoderm made up of a layer of flattened cells, a middle supporting layer, and an internal layer of entoderm composed of *collar-cells*. Each of these cells is provided with a whip-like projection of protoplasm (*flagellum*) (see p. 471), at the base of which is a collar-like projection. By the lashing movements which these threads execute the water-currents upon which the life of the animal depends are produced. The middle supporting layer is comparable to the similarly-placed gelatinous layer of a jelly-fish, and it contains numerous cells of various kinds which have been derived from the ectoderm and entoderm. Some of these

cells produce three-rayed calcareous spicules which form a very characteristic skeleton (fig. 298).

The majority of sponges, like corals (p. 476), are able to produce colonies of the most varied shape by processes of budding or splitting, and in such cases the boundaries between the individuals are usually very ill-marked, though the number of these

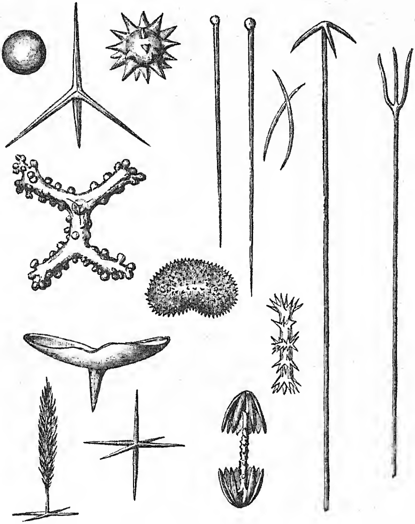


Fig. 298.—Sponge Spicules, enlarged

is generally to be told by counting the number of larger openings or oscula which are present. There is also a very large amount of variation in the nature of the skeleton and the extent to which it is developed. It may, as in the simple case described, be made up of scattered spicules, and these may either be calcareous or siliceous. Such spicules are of many different shapes (fig. 298), and they may be compacted into a firm, continuous mass, while they may further be associated with, or replaced by, a complex horny net-work. It should further be remarked that in the large majority of cases the body-wall is much more complicated than

in the case described, and the collar-cells are restricted to small rounded chambers situated in the thickness of the wall and communicating by narrow canals with the exterior on the one hand and the central cavity on the other. The canal system may be exceedingly complex, as may be realized by looking at the labyrinth of spaces present in an ordinary bath-sponge.

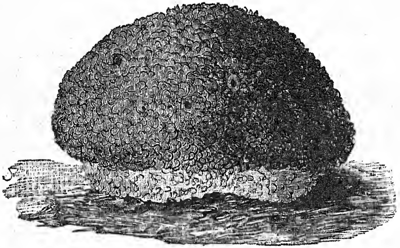


Fig. 299.—Bath-Sponge (*Euspongia*), reduced

It will be sufficient for the present purpose to consider the Sponges as divided into two groups according to the nature of the skeleton; *i.e.*: 1. Calcareous Sponges, and 2. Siliceous Sponges.

1. *Calcareous Sponges*, when simple, correspond to the type described. A more complex example is afforded by the common British species *Grantia compressa*, a small white flattened sponge about an inch long, frequently found attached to stones and other objects between tide-marks. Other forms are represented in fig. 300.

2. *Siliceous Sponges* include a great variety of forms in which the supporting spicules, when present, are of siliceous or flinty nature. One of the commonest British species is the *Bread-crumb Sponge* (*Halichondria*), which, in the form of yellowish-brown or orange-coloured masses, may be found encrusting rocks near low-tide mark. On the surface of the sponge a number of little conical elevations may be seen, and on the end of each an *osculum* is situated. The *pores* by which currents enter are placed in the part of the sponge between these projections. For beauty of form nothing can surpass *Venus's Flower-Basket* (*Euplectella*), a deep-water form in which the skeleton may be compared to a cornucopia with a wall of lace-like appearance and a perforated lid. Another very interesting kind is the *Glass-rope Sponge* (*Hyalonema*) dredged in deep water off Japan. Here the ovoid body is anchored in the mud by bundles of long twisted spicules which have suggested the name.

The *Bath-Sponge* (*Euspongia*) possesses a horny skeleton, the texture of which makes it useful for a variety of purposes.

One small group of sponges is found in *fresh water*, and of

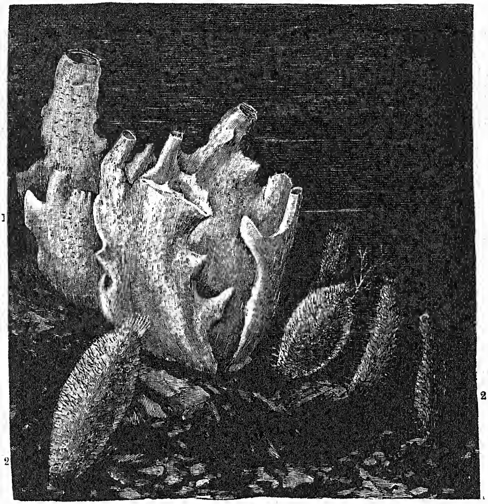


Fig. 300.—Group of Calcareous Sponges 1, *Leucandra aspera.* 2, *Sycandra raphanus*

these the commonest British genus (*Spongilla*) is found as a greenish crust upon various objects.

ANIMALCULES (Protozoa)

The innumerable host of simple animals which constitute this phylum are nearly all minute, while many of them can only be studied by the highest powers of the microscope, so that every improvement in the construction of that instrument has been followed by the acquisition of fresh knowledge concerning this group. Very great interest attaches to the study of the Protozoa, for here we have to deal with life under the simplest conditions, and find the actual living substance, *protoplasm*, which

constitutes the essential part of all organisms, in a comparatively pure form, and not obscured to the same extent as in higher animals by the products of its own activity. It has become a tradition to take as a first type one of the simplest members of the group, *i.e.* the *Proteus Animalcule* or *Amœba*, which is commonly found creeping on the mud of ponds.

Reference has frequently been made to the microscopic bodies known as white or colourless corpuscles which abound in the blood and lymph of higher animals (see p. 41). These crawl through the body in all directions and perform various functions of no mean importance, one being that of destroying disease germs which have entered the organism from the exterior. These corpuscles may almost be said to lead an existence independent of the rest of the body, and indeed it is possible to keep them alive outside the organism to which they belong for some time, especially in the case of cold-blooded creatures such as the Frog. An Amœba resembles in many essential respects one of these corpuscles, so much so that when it cannot be obtained for study in the laboratory a white corpuscle is often taken as the best substitute. The body (fig. 301) consists of a particle of semi-fluid protoplasm possessing the power of active locomotion, employed in the search for *food*, which consists of microscopic plants and other solid bodies of organic nature. The complex and solid nature of the food, or part of it, is, as will be elsewhere shown, a characteristic of average animals as compared with average plants, and the powers of locomotion with which most animals are endowed has an obvious relation to this. In such a *fixed animal* as a sponge there is, as we have seen, a special arrangement by which food is brought to the body, compensating for the absence of locomotor powers. An ordinary *green plant*, feeding as it does upon gaseous and liquid food extracted from air and soil, has no need for powers of locomotion, and its branching form gives a very large surface through which the simple food can diffuse. An active *animal*, on the other hand, such as Amœba, has a compact body which is clearly more convenient for locomotor purposes and less exposed than a branching form would be to the attacks of enemies. When tree-like organisms, such as zoophytes, are of animal nature, they usually represent fixed colonies to which food is brought by currents.

The body of a living Amœba is seen to be constantly changing

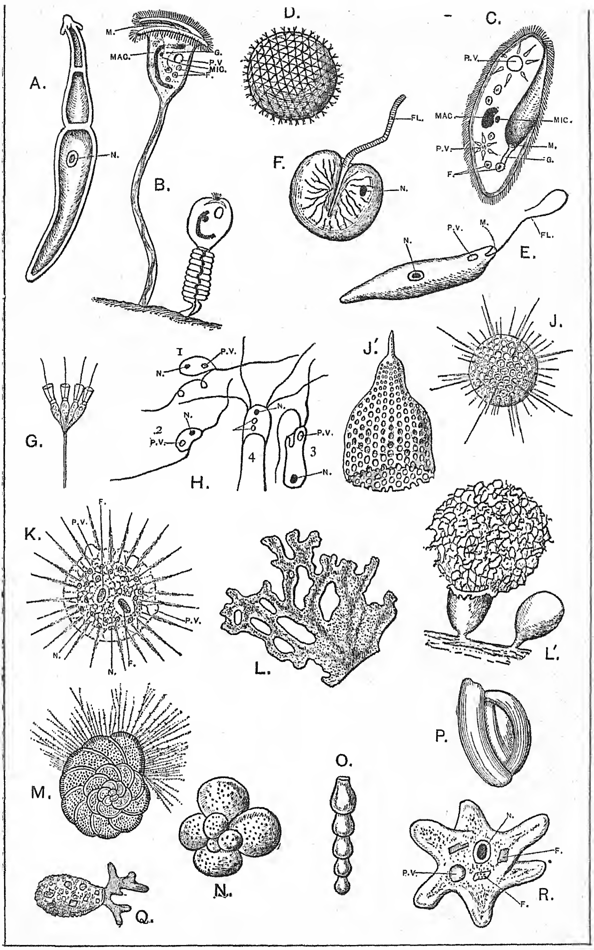


Fig. 301.—Protozoa, enlarged to various scales. Reference letters:—F, Food; FL., flagellum; G, gullet; M, mouth; MAC., macronucleus; MIC., micronucleus; N, nucleus; P.V., pulsating vacuole

A, Cockroach Gregarine (*Clepsidrina blattarum*). B, Bell-Animalcule (*Vorticella*), extended and retracted. C, Slipper-Animalcule (*Paramæcium*). D, Volvox. E. Euglena. F, Noctiluca. G, Codonocladium. H, Monads: 1 and 2, Springing Monad (*Heteromita*); 3, *Chilomonas*; 4, *Hexamita*. J and J′, Skeletons of Radiolaria (*Heliosphæra* and *Eucyrtidium*). K, A Sun-Animalcule (*Actinosphærium*). L and L′, Small piece of a Mycetozoon and two capsules (one ruptured) of same. M, A Foraminifer (*Rotalia*), with protruded threads of protoplasm. N. O. P. Shells of Foraminifera (*Globigerina*, *Nodosaria*, and *Miliola*). Q, A shell-bearing

its shape, blunt lobes of the protoplasm (pseudopods) being protruded from time to time. They are not constant structures, but can be formed and again obliterated at any part of the body—at least in the commonest species of Amœba. Not only do these lobes enable the animal to crawl about, but they also serve to secure food particles, engulfing them, so to speak. No breach is formed thereby, for any hole temporarily made in the semi-fluid protoplasm at once closes up without leaving any trace. Once within the protoplasm the food is digested, and the undigested portions of it are cast out from any part of the body. In the case of Hydra some of the endoderm cells take in and digest solid particles in much the same way (p. 471).

The simple body of Amœba presents but little distinction of parts, but the outer part of the protoplasm is clearer and perhaps somewhat denser than the inner part into which the food is taken, and which also contains, as a rule, numerous granules of various nature. As in a colourless blood corpuscle a small rounded particle of specialized protoplasm, the *nucleus*, can be distinguished, and this appears to have a great deal to do with regulating and controlling the nutrition and other functions. Its presence shows that Amœba is a single *cell* or unit of structure, *i.e.* is unicellular. The body of Hydra, and the same thing is true for all animals higher than the Protozoa, has been compared (p. 469) to a house composed of various building materials of which the units are bricks, blocks of stone, and the like, these materials being likened to the *tissues* of the animal in which *cells* of differing kind are the constituent units. An unicellular creature like Amœba may therefore be compared to a house built of one brick, if such a metaphor can be regarded as thinkable. The PROTOZOA indeed are defined as animals in which the body is made up of one cell only, or at most of an aggregate of cells which are not specialized into tissues, so that each member of the aggregate has to perform all the functions of life. The remaining thirteen phyla of animals are often grouped together as METAZOA, in which the body is made up of more or less numerous cells specialized to form tissues. It may be as well to express this in tabular form, advantage also being taken of the opportunity to show the limits of Vertebrata and Invertebrata, of Diploblastica and Triploblastica.

There can be no doubt that the Metazoa are descended from unicellular forms, which must have resembled some of the

	I. VERTEBRATA	Triploblastica	Metazoa.
Invertebrata	II. Nemertea	Triploblastica	Metazoa.
Invertebrata	III. Mollusca	Triploblastica	Metazoa.
Invertebrata	IV. Arthropoda	Triploblastica	Metazoa.
Invertebrata	V. Annelida	Triploblastica	Metazoa.
Invertebrata	VI. Gephyrea	Triploblastica	Metazoa.
Invertebrata	VII. Rotifera	Triploblastica	Metazoa.
Invertebrata	VIII. Molluscoida	Triploblastica	Metazoa.
Invertebrata	IX. Platyhelmia	Triploblastica	Metazoa.
Invertebrata	X. Nemathelmia	Triploblastica	Metazoa.
Invertebrata	XI. Echinodermata	Triploblastica	Metazoa.
Invertebrata	XII. Cœlenterata	Diploblastica	Metazoa.
Invertebrata	XIII. Porifera	Diploblastica	Metazoa.
Invertebrata	XIV. PROTOZOA		

Protozoa, and consequently great interest attaches to the study of those members of the latter group which are aggregates of cells, since some of these may, in some respects, be like the transitional forms.

Returning to the consideration of Amœba, we find that this differs from a colourless corpuscle in possessing a liquid-filled space within the protoplasm which is constantly changing its size in a regular manner, and is therefore termed a *pulsating vacuole.* If carefully watched in a living specimen placed under the microscope, this will be found to slowly expand to a certain size and then to suddenly contract so as to be entirely lost to view, soon reappearing, however, at the same spot. It appears to communicate with the exterior, and probably has to do with getting rid of waste products (*excretion*) and perhaps also with the introduction of dissolved oxygen into the body for the purpose of *respiration.*

Amœba is *sensitive* to external influences, being affected, for example, by changes of temperature, but it also appears to be able to execute movements, apart from the direct action of such influences. Otherwise expressed, the minute fragment of protoplasm which constitutes the body of this animal, performs those functions which, in higher forms, are relegated to a *nervous system,* and its connected *sense organs.*

Careful observation has shown that Amœba multiplies itself by a process of splitting or *fission,* as observed in some animals higher in the scale (pp. 476). The nucleus elongates, and becomes divided into two parts, and at the same time the rest of the body is halved, the result being that the parent animal disappears altogether as an individual, being replaced by two new animals which subsequently increase in size.

It therefore appears that all the functions of life can be, and are, performed by a single cell, this having to discharge the duties which in higher organisms are distributed between different complex organs and tissues.

It is convenient to divide the Protozoa into three groups:—1. Infusorians (Infusoria); 2. Amœba-like Protozoa (Rhizopoda); and 3. Gregarines (Sporozoa).

Group 1.—Infusorians (Infusoria)

If boiling water is added to chopped hay or other vegetable matter, and the infusion so procured allowed to stand for some time, it will begin to putrefy, and a large number of minute active creatures will make their appearance in it. The same thing would happen if the infusion were of animal nature. The term *Infusoria* was first applied to the minute forms noted in various decomposing substances of the kind just mentioned, but they are by no means invariably associated with putridity, and abound both in salt and fresh water, or even on damp soil and vegetation.

A very common form is the *Slipper Animalcule* (*Paramœcium*) (fig. 301), which is readily obtained by making an infusion of hay as described. It is an active whitish creature, just visible to the naked eye. Placed under the microscope, it will be found to possess an elongated body, which, unlike Amœba, has a definite shape owing to the fact that the outer layer of the protoplasm (ectosarc) is firmer than the rest (endosarc), and covered by a thin elastic membrane or *cuticle*. As another consequence of this, food cannot be taken into, or solid waste ejected from, any part of the body, but there is on one side a depression which leads to a *mouth*, and this again into a very short *gullet*, that ends abruptly in the soft internal protoplasm (endosarc). Not far from this depression there is a spot where the cuticle is absent, and the solid refuse from the food can pass out to the exterior.

The presence of a cuticle, and the firm nature of the outer protoplasm, prevent the formation of the blunt lobes (pseudopods), which, as we have seen, serve in Amœba as organs for obtaining food and effecting locomotion. Their place is here taken by a uniform covering of *cilia*, which are protruded through minute holes in the cuticle. By them the animalcule is rowed about from place to place, and they also set up currents by which food particles

are conducted into the mouth. Within the body two *pulsating vacuoles* can be seen, one at each end, and there are also two bodies of nuclear nature, which are placed close together. One of them is large (macronucleus), and the other small (micronucleus). They pass through a series of very complicated changes before the animal undergoes transverse splitting or *fission*, which is here the characteristic method of multiplication.

A very large section of the Infusoria are characterized by the presence of cilia, the arrangement of which differs in different species, and these constitute the group of *Ciliata*. We may take as a second example of this division the *Bell Animalcule* (*Vorticella*) (fig. 301), which is commonly found attached to water-weeds, or it may be to aquatic animals, such as the little red worm Tubifex (p. 431). Here the body is of bluntly conical form, with the narrow end drawn out into a long *stalk*, firmly fixed to the object upon which the animal lives. When fully expanded, it can be seen that the cilia are limited to the broad end of the body, on which they are arranged in a short spiral, while smaller cilia are continued down into a depression, which may be compared to that seen in the Slipper Animalcule, for it leads into a short gullet of the same kind. Within this depression there is a soft spot through which the undigested remains of the food are ejected. The wreath of cilia produces currents, which set into and out of the mouth-depression, carrying food and dissolved oxygen inwards and waste matters outwards. As in a Slipper Animalcule, the protoplasm is divided into a softer central *endosarc* and a firm external *ectosarc*, the latter being continued into a fibre which runs in a wavy manner through the stalk. If Vorticella is alarmed in any way, the free end of the body is folded in, and, at the same time, the elastic stalk is thrown into the form of a spiral by the shortening or contraction of the fibre it encloses.

Within the body one *pulsating vacuole* can be seen, and also two *nuclei*, the big one having a very characteristic horse-shoe form. Multiplication is effected by longitudinal splitting, one of the two new individuals remaining on the stalk, while the other becomes detached, being rowed about by the cilia till a suitable spot is reached, when it becomes attached, and develops a new stalk.

Some of the near relatives of the Bell Animalcule form colonies by means of fission, the new individuals remaining attached instead

of at once becoming separated, as in Vorticella. All the members of the colony are of exactly similar nature.

Another large section of Infusorians, the *Flagellata*, is characterized by the presence of those protoplasmic threads known as *flagella* (p. 471), which, though allied to cilia, are capable of executing much more complex movements, and are not present in large numbers on the same cell. A common example is *Euglena* (fig. 301), a minute green form with worm-like body, found, sometimes very abundantly, in stagnant water. At the front end there is one long *flagellum*, which acts as a swimming organ, pulling the body after it through the water. At its base there is a minute *mouth* leading into an exceedingly short *gullet*, near which is a *pulsating vacuole*, and a red *pigment-spot*. The nucleus is central, and the green colouring matter (chlorophyll), which is of the same nature as that found in ordinary plants, is contained in specialized parts of the protoplasm. The body is constantly altering its shape in a peculiar manner, but the presence of a firm *cuticle* prevents the formation of pseudopods.

Putrefying infusions contain vast numbers of very minute flagellates, commonly known as *monads* (fig. 301). A well-known form is the *Springing Monad* (*Heteromita*), so named from the character of its movements. It is shaped like a bean, and possesses two long *flagella*, attached near the notched side. One of these is extended forward during locomotion like the single flagellum of Euglena, while the other is trailed behind.

A very interesting section of the present group contains simple and colonial forms, in which the individuals closely resemble the *collar-cells* of sponges (see p. 484). *Codonocladium* (fig. 301) may be taken as an example. The interest chiefly lies in the fact that such forms perhaps give a hint as to the ancestry of the sponges.

It has been mentioned that Euglena is like a green plant, inasmuch as it contains chlorophyll, but the presence of a mouth proves it to be an animal. There are, however, certain flagellates which are coloured green by this pigment, and at the same time are devoid of any mouth-opening. Indeed, many botanists claim them as plants. Some are simple, others colonial, and of the latter, one genus is particularly well known on account of its great beauty as a microscopic object. This is *Volvox*, a form shaped like a hollow sphere (fig. 301), and about the size of a very small pin's head. At regular intervals in the wall of the sphere are

imbedded the green pear-shaped individuals, each of which is provided with a pair of *flagella*, and is connected by threads of protoplasm with its neighbours. The colony swims about by means of the flagella, slowly revolving as it does so. We have here an example of the most perfect type of symmetry known, that of the sphere, a shape which is only possible when external influences act on all parts alike, as can only be the case with a revolving aquatic form. At times, however, the symmetry of Volvox is disturbed by the specialization of certain cells for the purpose of propagation.

A small marine group of flagellates is represented by the remarkable form *Noctiluca* (L. *nox*, night; *lux*, light), countless myriads of which are sometimes found floating together in the sea (fig. 301), and are one of the causes of the phosphorescence common in the summer months. Each individual is of comparatively large size ($\frac{1}{25}$ of an inch in diameter) and is shaped like a peach, a very large *flagellum* being attached at one end of the groove. The *mouth* is situated at the base of this structure and leads into a short *gullet* into which a second but smaller flagellum projects.

Group 2.—Amœba-like Protozoa (Rhizopoda)

A description has already been given of the Proteus Animalcule (Amœba), which may be taken as a type of the group, all the members of which are provided with those projections of the body which are called pseudopods, though it is only in some cases that these are broad lobes, as in many species of Amœba.

There are a number of common fresh-water members of this group (fig. 301), which essentially resemble Amœba except that they possess a shell of varied nature and shape. Sometimes it consists of foreign particles cemented together, and at other times it is entirely made up of material presumably of horny nature formed by the activity of the protoplasm.

Cases like those just mentioned lead on to a large and important group found both in salt and fresh water, and characterized by the presence of a shell that is often riddled with minute pores or *foramina*, on which account the name of *Foraminifera* has been given (fig. 301). The shell may be either tough and membranous, composed of foreign particles agglutinated

together, or, and usually, of calcareous nature. It either consists of a single chamber or of a number of chambers associated in various manners and presenting the utmost variety in form. One of the most abundant forms is *Globigerina*, the shell of which consists of several rounded chambers united together, and which occurs in such profusion in a calcareous deposit covering large tracts of the ocean floor that this has received the name of Globigerina ooze. Globigerina and other forms have also lived in earlier epochs of the earth's history, playing a very important part as rock-builders. The pure form of limestone called chalk is, for example, mainly composed of such remains. Most of the Foraminifera are of small size, but *Nummulina*, so called from its coin-like shape (L. *nummus*, a coin), reaches the size of a shilling piece. Its shells chiefly make up the important nummulitic limestone by which mountain ranges in the Mediterranean region are to a large extent built up.

The *pseudopods* of the Foraminifera are slender threads which often unite together into a sort of net-work. More than one *nucleus* is commonly present in the protoplasm of which the soft body consists.

The *Sun-Animalcules* (*Heliozoa*) (fig. 301) are a group of mainly fresh-water forms in which the body is spherical, and stiff pointed pseudopods radiate from it in a way which suggests the rays seen in the conventional representation of the sun; hence the name. There may be more than one nucleus and pulsating vacuole. *Actinophrys* and *Actinosphærium* are typical genera. In some members of the group the surface of the body is covered by loose flinty *spicules*, and in the stalked genus *Clathrulina* there is a continuous shell in the form of a perforated hollow sphere. This leads on to the condition found in most of the marine group of *Ray-Animalcules* (Radiolaria) (fig. 301), where there is a siliceous shell of extreme beauty and of the most varied shape. Some parts of the sea-floor are covered by Radiolarian ooze, mainly composed of such shells; and there are also fossil forms making up certain rocks, notably in the Barbados. Almost every microscopic cabinet contains a slide of this "Barbados earth".

The Amœba group may be reckoned to include certain problematic organisms called Myxomycetes or *Mycetozoa*, the latter name indicating the doubt which has existed as to whether

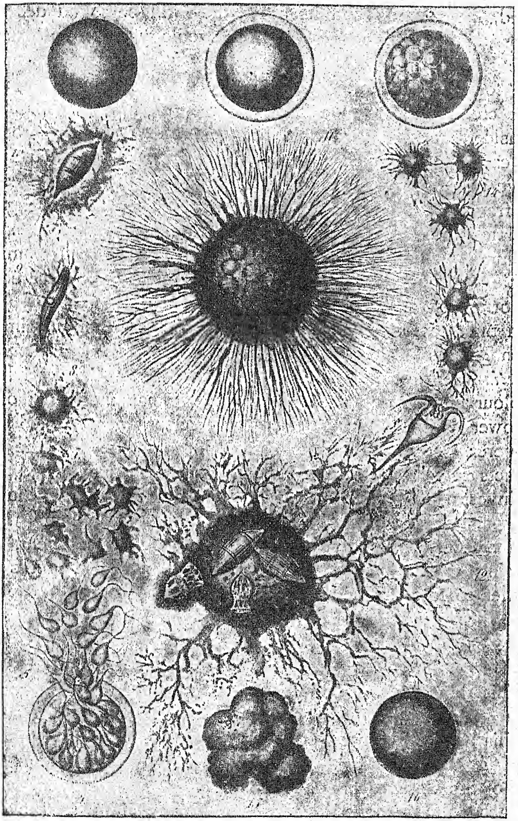


Fig. 302.—Stages in Life-History of *Protomyxa*, enlarged

1, Spherical resting stage; 2, the same invested with firm coat; 3, contents of same dividing into spores; 4, escape of spores (5), which assume amœba-like shape, feed (9 and 10), and fuse together (13, 14) to form adult stage, which is shown in hungry stage (11), and feeding (12). This ultimately contracts (15), and becomes round (16), after which the life-cycle recommences as before.

they are plants or animals (Gk. *mykēs*, a fungus; *zōon*, an animal). Indeed, like Volvox and its allies, they will be found described in most text-books, both of botany and zoology. A good example is the so-called "flowers of tan" (*Æthalium*) (fig. 301), which is to be found in the form of sulphur-coloured net-works of protoplasm creeping slowly over heaps of spent tan, and attaining a considerable size. At a certain time this organism produces little capsules in which a number of small hard-coated reproductive bodies known as *spores* are formed. From these escape little fragments of protoplasm, which are at first something like flagellate protozoans, for each of them possesses a single flagellum, while later on they assume the shape of minute amœbæ. A number of these fuse together to form a creeping net-work.

In the Amœba group we may also include one of the simplest known kinds of Protozoa, a minute marine animal—*Protomyxa aurantiaca* (fig. 302)—found on the coast of the Canary Islands. In colour and appearance it resembles a small individual of the tan-flower organism, but no trace of a nucleus was observed by its discoverer. After leading an active life for some time the body contracts into a spherical form and becomes surrounded by a firm investment. The protoplasm then divides up into a number of fragments, each of which possesses a single flagellum. These are liberated by the rupture of the protecting investment, soon assuming the shape of little amœbæ, of which numbers fuse together to form an adult.

Group 3.—Gregarines (Sporozoa)

This third and last group of the Protozoa has been modified by the parasitic habit. The body is covered by a firm cuticle, but cilia as well as pseudopods are absent. A good example is a form (*Clepsidrina blattarum*) (fig. 301), found within the alimentary canal of the Cockroach. The elongated body, when very young, is attached by a hooked narrower end to the lining of the cockroach's intestine. Later on, the hooked end is shed, the animal becoming free. A *nucleus* is discernible within the protoplasm, but no pulsating vacuole. As the name indicates, the group is characterized by the presence of those specialized reproductive cells called *spores*, which are more commonly met with in plants

than in animals. Before these can be formed two individuals must together be surrounded by a firm coating or *cyst*, and they then break up into a multitude of little spores surrounded by firm coats. The spores become free by a somewhat complex process, the firm coat of each then ruptures, and the contained protoplasm emerges, ultimately growing into an adult Gregarine, which is at first imbedded in and nourished by one of the cells lining the intestine of the cockroach.

The Sporozoa not only include many forms more or less similar to the one described, but also a large number of much simpler species, parasitic in the cells of Vertebrates and other higher animals.

END OF VOL. I